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THE CONTROL OF INTRACTABLE PAIN IN LUMBAR REGION, PELVIS AND LOWER EXTREMITIES

BY SECTION OF THE ANTEROLATERAL COLUMNS OF THE SPINAL CORD (CHORDOTOMY)*

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The intense, intractable pain associated with primary or metastatic growths in the spine has always elicited the sympathy of the medical profession, but our efforts to afford adequate relief have in general been unsatisfactory. Almost as futile have been our attempts to alleviate the pain of inoperable uterine carcinoma with extensive pelvic metastases and of advanced malignant disease in the lower extremities. This pain, while sometimes not as severe as that associated with spinal cord lesions, is still accountable for an untold amount of suffering.

The routine administration of morphine in ever increasing doses and at shorter intervals has been almost universally accepted as the only palliative means at our disposal. Those of us, however, who have seen these patients linger on week after week and even month after month, begging for something to relieve their suffering, have felt at times as though almost any means is justifiable. Unfortunately morphine, while so efficacious in most diseases, has here proved unsatisfactory; a dose sufficient to benumb the mentality is required to control the pain. A tolerance for the drug is quickly acquired and as the disease may continue for months, enormous doses are ultimately needed to afford even partial relief.

It is for this reason that numerous surgical procedures for the abolition of pain have from time to time been suggested. The operation that has been most frequently applied is that of rhizotomy. Dana first proposed division of the posterior roots for the relief of severe neuritic pains, and following his suggestion Bennett in 1886 and Abbe in 1888 divided certain posterior nerve roots. In 1908 Förster recommended rhizotomy for the relief of gastric crisis. Since that time a rather large number of patients have been operated on with varying degrees of relief. On the whole the operation has fallen into ill repute.

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Theoretically, rhizotomy should give perfect relief but practically the results have been disappointing. Many of the operations undoubtedly failed because an insufficient number of nerve roots were cut. This explanation, however, is not always applicable. Elsberg [1] says:

> I have never seen a good result when the operation was performed for the pain of metastatic malignant disease or arthritis of the vertebrae, no matter how large the number of roots divided.

He points out that while nerve root neuralgias, as from direct bony or inflammatory pressure, can with almost complete certainty be cured by rhizotomy, pain from peripheral lesions may be unchanged and suggests that the wide anastomosis of peripheral nerves may account for the failures in the latter group. Frazier [2] has had much the same experience. He says:

> Unfortunately, the results of posterior root section for the relief of intractable pain have not fulfilled the expectations of the inceptors of the operation; and while chronologically pain is the primary indication for rhizotomy, this operation has been found to be much more effective in the treatment of spasticity and visceral crises, to which it was later extended.

Not only does rhizotomy frequently fail to afford relief, but there are at least two serious disadvantages to the operation. Because of the wide overlapping of the sensory nerves it is imperative that at least three consecutive roots be divided to obtain anesthesia in even a small area. It is therefore evident that at least two roots both above and below the particular segments that we wish to anesthetize must be sectioned. In malignant growths the area of pain is usually large, requiring an extensive laminectomy, frequently in these weakened patients a hazardous procedure.

The second objection to rhizotomy is the complete anesthesia that inevitably accompanies the complete analgesia. Loss of pain and temperature sense in no way seriously inconveniences the patient, but the additional loss of sensations of touch, motion and position is a definite handicap. To overcome this complication every third root may be left intact. While this will insure some touch sensation it unfortunately will not completely abolish pain. Partial or complete paraplegia and incontinence of urine have been described as occasional complications of root section. Other operations on the posterior roots, their ganglions, or on the peripheral nerves have proved even less satisfactory.

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1. Elsberg, C. A.: Diagnosis and Treatment of Surgical Diseases of the Spinal Cord and Its Membranes, Philadelphia, W. B. Saunders Company, 1916, p. 153.

2. Frazier, C. H.: Surgery of the Spine and Spinal Cord, New York, D. Appleton & Co., 1918, p. 629.

A still more radical procedure to relieve the excruciating pain associated with malignant spinal metastases was proposed by Cushing.[3] In 1910 he suggested "the deliberate transsection, either of the entire cord or of the posterior columns alone, cephalad to the lesion," and in 1916 performed such an operation.[4] The patient was a woman suffering from spinal metastases with a paralysis below the twelfth thoracic segment. He divided the cord in the thoracic region, well above the lesion, with an entirely satisfactory result, the patient being practically free from pain until the time of her death six months later. Such a radical operation would, of course, only be justifiable when the motor function was already lost, but the operation has been seriously proposed in a number of cases.

Knowing the drawbacks and uncertainties of the previously advocated procedures for the relief of intractable pain, we studied with growing interest Frazier's first series of chordotomies, based as they were on an exact knowledge of spinal cord topography. This operation was made feasible by the work of several men, particularly Spiller, who by clinical observations and experimental investigations laid the basis for our present knowledge of spinal pathways.

Van Gehuchten in 1893 first expressed the definite opinion that the fibers conveying pain and temperature sensations passed up the cord in Gowers' tract, although Gowers had suggested this in 1879. Others supported his views, but no actual proof was afforded until Spiller's[5] fortunate observaton of a patient at the Philadelphia General Hospital in August, 1904. This man had practically complete loss of sensation for pain and temperature in the lower limbs with preservation of tactile sensibility. He was under observation for some months and died in January, 1905. The necropsy revealed a solitary tubercle involving the right Gowers' tract at the extreme lower end of the thoracic cord and slightly above this a second solitary tubercle implicating the left tract of Gowers.

This absolute localization of the pain fibers and the evidence that no important motor or tactile sensory fibers passed in this tract led Spiller in 1911 definitely to propose section of the anterolateral column for intractable pain. It had previously been suggested by Schüller (1910) as a substitute for section of the posterior roots in cases of

3. Cushing, Harvey: The Special Field of Neurological Surgery: Five Years Later, Bull. Johns Hopkins Hosp. **21**:325 (Nov.) 1910.

4. Cushing, Harvey: The Special Field of Neurological Surgery After Another Interval, Arch. Neurol. & Psychiat. **4**:603 (Dec.) 1920.

5. Spiller, W. G.: The Occasional Clinical Resemblance Between Caries of the Vertebrae and Lumbothoracic Syringomyelia, and the Location Within the Spinal Cord of the Fibers for the Sensations of Pain and Temperature, Univ. Penn. M. Bull. **18**:147 (July-Aug.) 1905.

gastric crisis. Later observations have convinced Spiller that the fibers of pain and temperature sensation lie slightly more mesial in the anterolateral columns than in Gowers' tract proper.[6]

The first operation of chordotomy with division of the pain and temperature fibers was performed by Martin at Spiller's request.[7] The patient had a malignant growth in the spinal cord with severe pain in the pelvis and lower limbs. The operation was done Jan. 19, 1911,

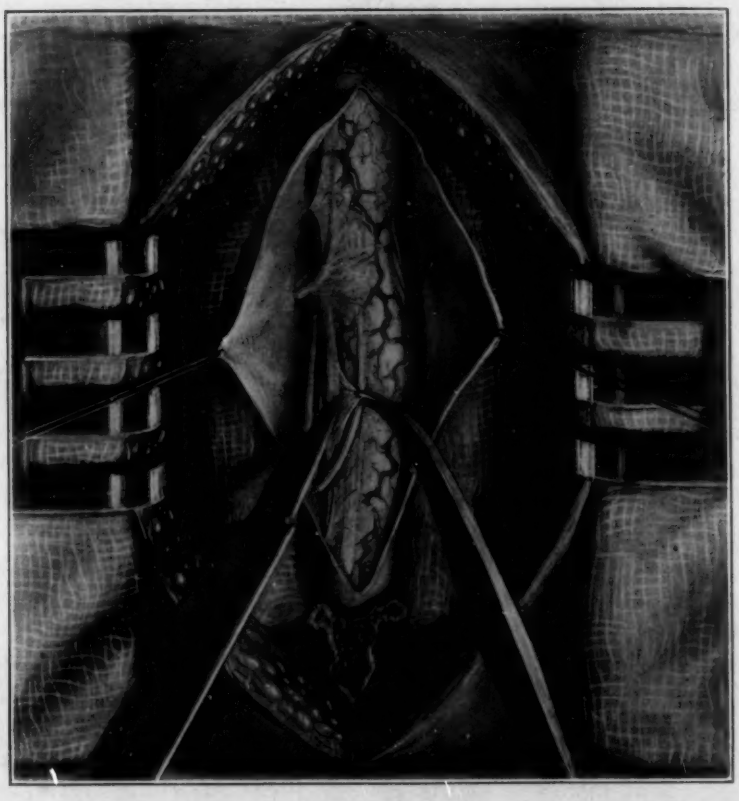

Fig. 1.—Left anterolateral tract: the arachnoid has been freed, the attachment of the dentate ligament divided and the cord rotated; the knife is about to be inserted just in front of the reflection of the dentate ligament from the cord.

both anterolateral columns being divided to a depth of about 2 mm. at a point opposite the seventh dorsal vertebra. Pain was much diminished

6. Spiller, W. G.: Remarks Before the American Neurological Association, Arch. Neurol. & Psychiat. **4**:575 (Nov.) 1920.

7. Spiller, W. G., and Martin, Edward: The Treatment of Persistent Pain of Organic Origin in the Lower Part of the Body by Division of the Anterolateral Column of the Spinal Cord, J. A. M. A. **58**:1489 (May 18) 1912.

and Spiller regarded the result as successful when he reexamined the patient more than a year later.

At Spiller's suggestion confirmatory experimental work was then undertaken by Cadwalader and Sweet.[8] They came to the conclusion that sensations of pain and temperature were abolished or greatly impaired in the dogs in which they divided the anterolateral tracts.

Rothman carried out similar experiments and showed that the sensation of pain was carried in the anterior part of the lateral column. Rivers and Head proved that although there are two distinct mechanisms for the reception of painful stimuli, both these systems are grouped together in the anterolateral portions of the cord and therefore division of this tract on either side should give analgesia.

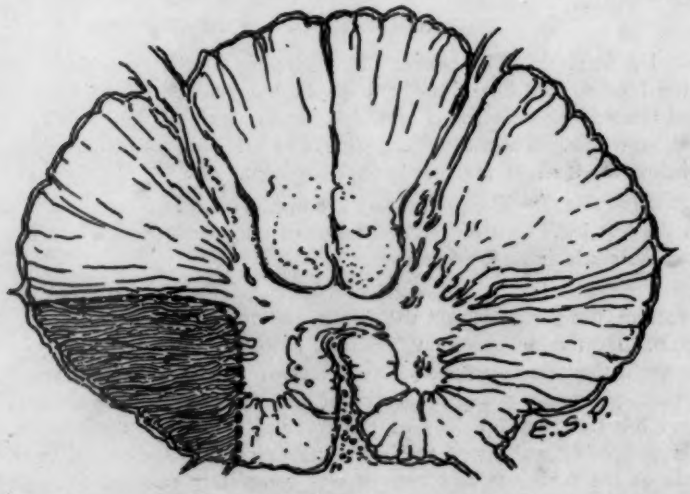

Fig. 2.—Spinal cord at level of fifth dorsal segment showing portion of cord included in section of an anterolateral tract.

The second chordotomy with section of an anterolateral column was performed in 1912 by Beer[9] for the relief of pain due to metastases from a carcinoma of the cervix. A malignant mass could be felt on the right side of the pelvis and the patient complained of severe pain on the right side in the lumbosacral region and in the right lower extremity. Chordotomy at the level of the tenth dorsal vertebra gave complete analgesia and loss of cold perception on the right up to a line roughly horizontal with the pubes. While the pain in the back was not relieved,

8. Cadwalader, W. B., and Sweet, J. E.: Experimental Work on the Function of the Anterolateral Column of the Spinal Cord, J. A. M. A. **58**:1490 (May 18) 1912.

9. Beer, Edwin: The Relief of Intractable and Persistent Pain Due to Metastases Pressing on Nerve Plexuses, J. A. M. A. **60**:267 (Jan. 25) 1913.

the patient was on the whole greatly benefited as the most severe pain, which had been referred to the leg, did not recur.

Later the operation was performed by Tietze at Förster's suggestion and by Elsberg, but it did not attract the attention it deserves until Frazier [10] in 1920 published a series of six cases. The results, except in one instance, were satisfactory and in this, the sixth, considerable relief was obtained. Since the operation is still comparatively new and much is yet to be learned, particularly in regard to the amount or area of analgesia obtained by cutting the anterolateral columns at various levels and at different depths, we have thought it advisable to summarize briefly the published cases. An abstract of Frazier's first series of six cases in which chordotomies were performed for the relief of pain follows.

SERIES OF SIX CASES

CASE 1 (Frazier).—The patient had a sarcoma of the spine with intense pain from the hips to the knees and cramps in the calf muscles. Complete relief followed bilateral chordotomy, 3 mm. deep, at the level of the ninth and the tenth thoracic vertebrae. Practically complete loss of pain and thermal sense was noted below the level of the first lumbar segment.

CASE 2 (Frazier).—The patient had a gunshot wound of the spine with intense pain in the left leg. Complete relief followed unilateral chordotomy between the fifth and the sixth thoracic vertebrae.

CASE 3 (Frazier).—In a case of carcinoma of the rectum, with severe pain in the rectum, the perineum and the thighs, radium treatment had given no relief from pain. Bilateral chordotomy, 2.5 mm. deep, between the levels of the ninth and the tenth thoracic vertebrae yielded "loss of thermal and pain sensation over the buttock, perineum, posterior aspect of the thigh and below the level of the knee" on the right but no loss of the thermal or pain sensations on the left. Temporary flaccid paralysis of the left lower extremity disappeared in two weeks. The pain in the perineum and rectum was completely relieved in spite of only unilateral analgesia. The results were satisfactory four years later.

CASE 4 (Frazier).—The patient suffered terrible pain in the gluteal region from a sarcoma of the thigh with pelvic metastasis; this was completely relieved by unilateral chordotomy between the seventh and the eighth thoracic vertebrae.

CASE 5 (Frazier).—The patient had pain in both lower extremities, the result of a gunshot wound of the spine. Bilateral chordotomy at the level of the sixth thoracic vertebra gave immediate complete loss of pain and temperature sensation below the umbilicus. Unfortunately the subsequent history is unavailable.

CASE 6 (Frazier).—The patient had received a shell wound of the pelvis with an injury to the sciatic nerve. There was severe pain in the right leg along the course of the nerve. A burning and shooting pain was located in the thigh from a point about 12 inches (30.4 cm.) above the knee to 3 inches (7.6 cm.) above the midpopliteal space and in the right foot. Touch, pain and temperature sensations were completely lost in the distribution of the sciatic nerve. Unilateral chordotomy between the sixth and the seventh thoracic vertebrae was performed.

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10. Frazier, C. H.: Section of the Anterolateral Columns of the Spinal Cord for the Relief of Pain, Arch. Neurol. & Psychiat. **4**:137 (Nov.) 1920.

There was a diminution of the pain sensation but not complete loss in the leg and lower part of the abdomen of the opposite side; the temperature sense was impaired over the same area. A paresthesia persisted in the sole of the right foot. The pain was relieved for three months and then returned, necessitating further surgical intervention (case 7, Frazier and Spiller).

Shortly after the publication of this article Leighton [11] performed four chordotomies, three for the relief of tabetic pain and one for pain resulting from spinal cord injury. His patients were much benefited.

CASE 1 (Leighton).—The patient had typical tabes dorsalis, with pain involving the right side of the trunk and the right leg. Unilateral chordotomy at about the level of the sixth thoracic vertebra gave complete relief from the pain in the right leg.

CASE 2 (Leighton).—The patient had traumatic myelitis in the lower thoracic region, with lancinating pains in both legs and severe pain in the abdomen. Bilateral chordotomy after removal of the laminae of the fifth, sixth and seventh thoracic vertebrae resulted in relief of pain in both legs and loss of pain and temperature sensation below the level of the twelfth thoracic segment.

CASE 3 (Leighton).—The patient had typical tabes dorsalis, with gastric crises and pains of lancinating character in both legs. Bilateral chordotomy between the fifth and the sixth thoracic vertebrae gave complete relief from pain in both the abdomen and the legs.

CASE 4 (Leighton).—The patient had typical tabes dorsalis, with shooting pains in both legs. Bilateral chordotomy after removal of the fifth, the sixth and the seventh dorsal laminae gave considerable relief for the four weeks the patient was observed. He had occasional pain in the feet and Leighton noted that apparently all the pain fibers were not divided.

Frazier and Spiller [12] in 1923 reported the following cases, seven of which were new, one, case 7, being case 6 in Frazier's previously published series.

SERIES OF EIGHT CASES

CASE 1 (Frazier and Spiller).—The patient had practically complete paralysis of both lower extremities, with attacks of excruciating pain in both legs, following a wound from a high explosive shell in the third and the fourth lumbar vertebrae. Two operations with section of the posterior nerve roots had been performed without benefit. Bilateral chordotomy, on the right at the fifth and on the left at the sixth thoracic segments, resulted in loss of subjective pain and in a delayed pain sense over the right thigh and the right side of the abdomen to the umbilicus, and a lost pain sense in the left leg and the left side of the abdomen to about 2 inches (5 cm.) below the umbilicus. The heat and cold sensations were lost up to 1 inch (2.5 cm.) above the umbilicus on the right and to about 2 inches (5 cm.) below on the left.

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11. Leighton, W. E.: Section of the Anterolateral Tract of the Cord for the Relief of Intractable Pain Due to Spinal Cord Lesions, Surg. Gynec. Obst. **33**:246 (Sept.) 1921.

12. Frazier, C. H., and Spiller, W. G.: Section of the Anterolateral Columns of the Spinal Cord (Chordotomy), Arch. Neurol. & Psychiat. **9**:1 (Jan.) 1923.

CASE 2 (Frazier and Spiller).—The patient suffered agonizing pain, the result of a sarcoma of the vertebrae involving the cord at the ninth thoracic segment; this was entirely relieved by bilateral chordotomy at the level of the fifth thoracic segment. Pain sensation was lost 2 cm. below the umbilicus on the right and almost entirely over the left side of the lower part of the abdomen. The thermal sensation on the right was lost 10.5 cm. and on the left 7.5 cm. above the umbilicus.

CASE 3 (Frazier and Spiller).—The patient had metastatic carcinoma from the breast to the fifth lumbar vertebra and both iliac bones, with sharp, shooting pains in the legs and the pelvic organs. Bilateral chordotomy at about the fifth thoracic segment gave complete relief from the pain and great disturbance of the temperature sensation to a level slightly above the umbilicus. The pain sensation was largely lost over the same area. There was loss of dorsal flexion in both ankles and toes.

CASE 4 (Frazier and Spiller).—The patient had severe pain of unknown origin in the left side of the rectum and vagina and in the sole of the left foot. Section of the right anterolateral column at the level of the fourth and the fifth thoracic spinous processes gave complete relief of pain on the left side. There was a temporary paralysis of the right lower limb which remained as a permanent though slight weakness. Later, pain developed in the right side of the bladder and vagina, in the right thumb, heel and posterior half of the outer border of the right foot, necessitating chordotomy on the opposite side.

CASE 5 (Frazier and Spiller).—The patient had carcinoma of the rectum, which had been treated with radium and later by a modified Kraske's operation. Severe pain was referred to the sacrum and both legs, particularly the right. Three grains (0.19 Gm.) of morphine was required daily. Bilateral chordotomy at the level of the tenth and the eleventh thoracic vertebrae gave complete relief of pain. The areas of analgesia were not tested. The patient died from meningitis on the thirteenth day, probably as the result of severe cachexia.

CASE 6 (Frazier and Spiller).—The patient had carcinoma of the cecum, which was removed, but later an inoperable recurrence was found. Practically constant pain was felt in the right lower limb, which was aggravated by walking. Morphine was not tolerated. A left anterolateral chordotomy between the fourth and the fifth thoracic vertebrae gave relief from the pain in the right leg. Two weeks later the pain sensation was markedly impaired, but not completely lost in the whole right lower limb. It was somewhat affected up to the level of the umbilicus. The thermal sensation was lost over the entire right leg and ice was called a pin prick to 2 or 3 inches (5 or 7.6 cm.) above the umbilicus. Very hot water was sometimes recognized in the same area. Six weeks after the operation the area of impaired sensation had diminished, pain, heat and cold being recognized immediately above Poupart's ligament. Later the pain sensation returned about the knee, but was lost above this point to the inguinal region.

CASE 7 (Frazier and Spiller; case 6 in Frazier series).—The patient had suffered an injury to the sciatic nerve from a high explosive shell. First, a chordotomy relieved the pain in the thigh and foot for two or three months. It returned only in the foot. Two years later pain in the foot was still present, with impaired pain perception to about 1 inch (2.5 cm.) above the umbilicus. A unilateral chordotomy was performed at the level of the fifth thoracic vertebra, one vertebra higher than at the previous operation. The pain in the foot was not completely relieved although there was a complete loss of pain and thermal sensation up to about 1 inch above the umbilicus on the right; then pain in the thigh

along the course of the sciatic nerve returned. The pain sensation had returned on the inner side of the leg from the knee to the sole. Resection of the saphenous nerve gave some relief for only a few days, so a third chordotomy was performed. Previous chordotomies had been made to a depth of 2.5 mm.; the third section of the left anterolateral column was made 3 mm. deep at the level of the tenth thoracic segment. This apparently gave relief although the patient still complained at times. There evidently was a marked psychic element present.

CASE 8 (Frazier and Spiller).—The patient had myelitis, with intense hyperesthesia around the upper part of the thorax. A bilateral chordotomy at the level of the first thoracic segment gave practically complete relief. The sensations for pain, heat, cold and touch were impaired, but not lost from the second rib to the fifth intercostal space on both sides. Sympathetic ocular phenomena were present from the damage to the first thoracic nerve.

Our series at the University Hospital comprises a group of nineteen cases, the clinical abstracts of which follow. While I performed all the operations and checked the postoperative findings, the cases have all been carefully examined by independent observers, particularly by Drs. C. D. Camp, J. L. Garvey, L. J. Foster and W. A. Smith of the neurologic department. Only the essential portions of the history and physical, neurologic and operative findings have been incorporated in this report.

We have followed the chart of Déjerine and Thomas in estimating the number of a cord segment by the number of the posterior spinous process at the level of the lesion. We thus add 3 to the numerical designation of an upper or middle dorsal posterior spinous process to designate the cord segment of the same body level: i. e., the fifth dorsal posterior spinous process lies over the eighth dorsal segment. A common practice is to add only 2, which is approximately correct if the vertebral body is considered as a landmark. However, the vertebral bodies cannot be palpated and for clinical use the posterior spinous process is the most convenient guide to a given level.

REPORT OF CASES

CASE 1.—Mrs. C. P., aged 40, suffered pain from metastases of carcinoma of the breast to the lumbar vertebrae, the pelvic bones and the left femur; a bilateral chordotomy was performed.

Ten months before admission she had the left breast amputated for carcinoma. Three weeks later a dull, aching pain developed in the left side of the pelvis and in the left thigh. The pain gradually increased in severity and extended to the lumbar region, the entire pelvis and both thighs. The slightest motion of the left leg produced the most excruciating pain. Morphine gave little relief.

There was a recurrence of the carcinoma in the scar of the breast amputation. The left leg muscles showed considerable atrophy. Roentgen-ray examination showed metastases to the head of the right tenth rib, the lumbar vertebrae, the left ilium, the ischium and the head of the left femur. Malignancy in the pelvic bones had extended into the true pelvis. The neurologic examination was essentially negative.

The pain was so severe and morphine gave such little relief that section of the anterolateral tracts was deemed advisable.

March 5, 1921, the posterior spinous processes and the laminae of the fifth and sixth dorsal vertebrae were removed. The right anterolateral tract was sectioned at the level of the fifth spinous process to a depth of 2.5 mm. at the pial reflection of the dentate ligament and the incision carried forward and outward to the exit of an anterior root. A similar incision was attempted on the left, but the dentate

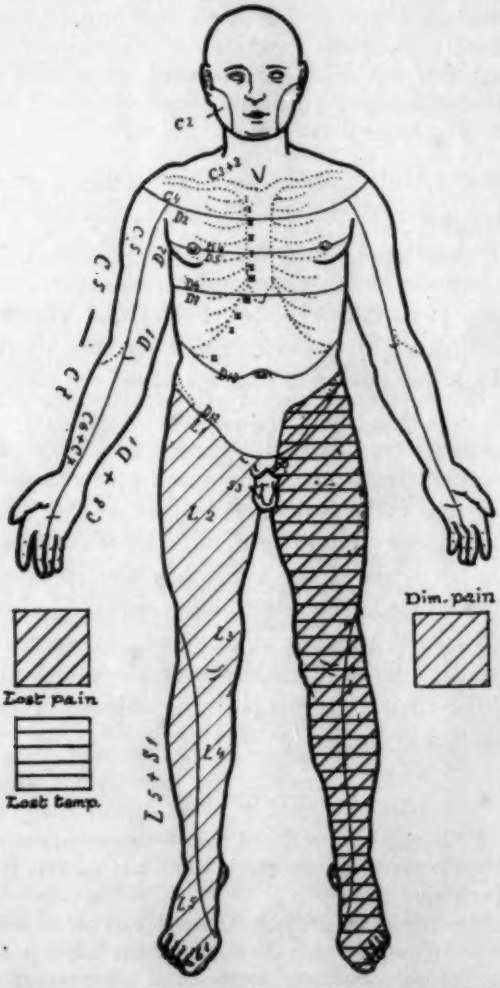

Fig. 3 (case 1).—Areas of lost pain and temperature and diminished pain eight days after bilateral chordotomy at level of eighth dorsal segment; depth, 2.5 mm. on right, slightly less on left; complete relief of pain.

ligament slipped from the forceps and our impression was that the incision did not extend as deeply as on the right.

Complete relief of the pain in the lumbar region, the pelvis and the legs was noted immediately after the operation. A neurologic examination by Dr. Camp

showed normal motion in the lower extremities and normal sense of motion and position. Vibratory and tactile sensations were normal. The deep pain sense and tenderness in Achilles tendon were lost in the left leg. The pain and temperature senses were lost on the left below the eleventh dorsal segment. There was no temperature loss but the pain sense was greatly diminished in the right leg up to the groin. The patellar and Achilles reflexes were normal. Plantar irritation caused flexion of the toes on each side (figs. 3 and 4).

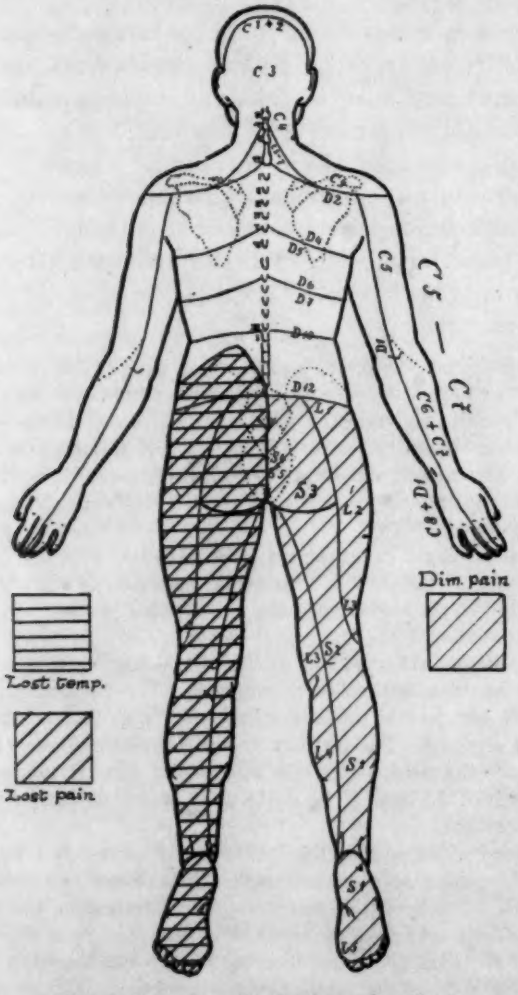

Fig. 4 (case 1).—Back view of patient.

One week after operation a pin point could be felt as such on the right leg but it elicited no pain. A pin point could not be distinguished on the left. Morphine had been used freely for some time before the operation, and the patient had acquired the habit. After the operation she complained of pain in one leg or the other whenever she thought morphine would be given. However, there was absolutely no pain on motion and none could be elicited in the pelvis or the

legs by pinching or pin prick. At times when she complained of pain, sterile hypodermic injections gave immediate relief. On other occasions, codeine appeared necessary. A report from her physician about five weeks after the operation stated that the pain had apparently returned in the left leg and hip, although in less degree. Catheterization was still necessary. Two and one-half months after the operation she was reported as complaining of much pain which appeared to be genuine, although the report added that there was no question but that she exaggerated her symptoms a great deal.

This, our first case, was encouraging but raised the question whether cutting the cord to a depth of 2.5 mm. was always sufficient. How much actual permanent relief of pain was obtained is difficult of determination. Certainly at first the relief was complete and for the twenty-four postoperative days she was in the hospital no pain could be elicited by the usual procedures. Morphine was not actually required to relieve the pain of which she regularly complained, although before operation this drug had given little relief. Whether the development of metastases at a higher level might have caused the pain referred to by her home physician is uncertain.

CASE 2.—Mrs. N. A., aged 50, had extreme pain in the lumbar region and pelvis due to carcinoma of the uterus; a bilateral chordotomy was performed.

The present trouble began about four months before admission with severe uterine hemorrhages associated with pain in the left lower quadrant and cramps across the lower part of the abdomen. Curettage showed far advanced medullary squamous cell carcinoma of the cervix. Radical cauterization with an actual cautery was performed.

Physical and neurologic examinations were negative with the exception of the extensive carcinoma of the cervix with pelvic metastases; cautery and roentgen-ray therapy gave no relief from pain. Morphine gave only partial relief. Chordotomy was advised.

July 27, 1921, the posterior spinous processes and laminae of the fifth, the sixth and the seventh dorsal vertebrae were removed. The right and the left anterolateral tracts were sectioned at the level of the fifth spinous process, approximately the eighth dorsal segment. The incision in each column commenced at the attachment of the dentate ligament to the cord and passed directly toward the center of the cord to a depth of 3.5 mm. The knife point was then carried forward to the exit of an anterior root.

She was relieved of all pain in the lumbar region and pelvis immediately after the operation. Morphine was discontinued. Codeine was required for the first three days because of pain in the shoulders. Catheterization was necessary until the patient was able to sit up on the ninth day. All motion in the lower extremities was lost for the first two days, then motion of the toes returned. Strength gradually returned and on the tenth day the patient could move her legs; she was walking well on the nineteenth day. This temporary paralysis was probably due to the fact that the cord incision was made slightly too far posteriorly.

Neurologic examination by Dr. Camp, August 18, showed no atrophy or deformity of the legs; no paralysis; the patellar, Achilles and plantar reflexes normal on both sides. Tactile, vibratory motion and position and localization senses were normal throughout the trunk and the lower extremities. The pain and temperature senses were lost up to about 1 inch (2.5 cm.) below the umbilicus on both sides (in the tenth dorsal segment).

Although this patient had a far advanced carcinoma of the cervix which had been estimated would cause death in two or three months, her general condition improved so greatly after the terrible pains were relieved that she returned after four months asking for her previous position in the linen department. She was sleeping well, had an excellent appetite and had gained weight. She was free from pain until her death a year and nine months after the bilateral chordotomy was performed. She had no weakness in the legs and was able to go about as she pleased. The pain and temperature sensations remained lost in both lower extremities. Her daughter reported after the mother's death that her mother had "felt fine" and that her physician said that this was the only case of uterine carcinoma in his experience which had not required opiates, at least toward the end.

CASE 3.—F. P., a man, aged 66, had pelvic metastasis from a carcinoma of the prostate; a bilateral chordotomy was performed.

Three years before admission the patient had a prostate operation because of retention. One year before admission he began to have severe pain in the lower part of the abdomen and pelvis, which had grown progressively worse. For several weeks morphine in large doses had been required.

Physical and neurologic examinations were negative except for an irregular hard mass occupying the region of the prostate. This tumor was about the size of an orange and was tender on palpation. Slightly to the left of the fourth lumbar vertebra was a very tender mass about the size of a small orange. A diagnosis of far advanced carcinoma of the prostate with pelvic extension was made. The pain was excruciating and not relieved by morphine.

Jan. 9, 1922, the posterior spinous processes of the third, the fourth and the fifth vertebrae and the laminae of the fourth dorsal vertebra were removed. A bilateral chordotomy was performed at the level of the sixth dorsal segment. The incision was carried to a depth of 3 mm. and extended from the dentate ligament to the anterior roots.

The postoperative convalescence was satisfactory except that catheterization was necessary. The patient complained of no pain below the umbilicus but did have pain in the chest. On the sixth day, he complained of severe pain in the bladder region although the skin up to the umbilicus was insensitive to pain. The urethra also was analgesic. The pain in the bladder was not constant and after a few days was only occasionally referred to.

Neurologic examination by Dr. Camp, January 23, showed normal motion in both extremities; deep and superficial reflexes unchanged; senses of motion, position, touch and vibration normal, and the pain and temperature senses lost below the area supplied by the tenth dorsal segment. He could not distinguish between a pin point and a pin head below the twelfth segment. Tenderness in the tendon of Achilles was lost on both sides.

He did not require morphine after the operation to relieve his first complaint, pain in the lower part of the abdomen and the pelvis. However, pain in the chest gradually increased and morphine was finally required to give relief. The latter pain was probably due to metastasis high up in the dorsal spine although this was never proved. The pain referred to the bladder may have been, as the examining neurologist thought, complained of simply to get morphine, as the habit had already been acquired. The exact mechanism of painful sensation in the bladder is not yet known, and it is possible that pain in this region could have been present although the overlying integument was completely analgesic

CASE 4.—Mrs. E. N., aged 35, suffered pain in the lower part of the abdomen, in the pelvis and the lumbosacral region caused by advanced carcinoma of the

uterus. A bilateral chordotomy was performed, and a second chordotomy was necessary.

She first noticed the present trouble one year before admission when she had a sudden uterine hemorrhage. A diagnosis of carcinoma of the cervix involving the body of the uterus was made at another hospital and seven radium treatments were administered. A biopsy here showed squamous cell carcinoma of the cervix. She has received roentgen-ray therapy and cauterization. For five months she had had pains in the lower part of the abdomen, in the pelvis, in the lumbosacral region and down the thighs. These pains were now severe and practically continuous. Large doses of morphine had been frequently required, but these were giving little relief at present.

Physical examination showed marked tenderness in both lower quadrants. The vaginal lymphatic glands on the right were enlarged and the neighboring vessels were greatly engorged. The cervix was replaced by a large cauliflower mass of malignant tissue which practically filled the vagina. The uterus was enlarged and fixed. The pelvis was filled with metastases. The right leg was markedly swollen with an induration about the ankle and calf. The left leg and ankle were somewhat swollen. Neurologic examination was negative.

Nov. 16, 1921, the posterior spinous processes and laminae of the second, third and foruth dorsal vertebrae were removed. The anterolateral columns at the level of the third spinous process (between the fifth and sixth dorsal segments) were sectioned to a depth of 2.5 mm., the incision extending from the attachment of the dentate ligament forward to the emergence of an anterior root. The arachnoid was much thickened and adherent to the dura and the cord, probably from some previous infection.

The patient was free from pain in the lower part of the abdomen and the lumbosacral region for ten days. Examination the day after operation showed complete loss of pain and temperature senses below the level of the eighth dorsal segment. Three days later a neurologic examination by Dr. Camp showed the pain and temperature senses returned but there was considerable delay in perception and summation phenomena were marked in the area in which they were previously lost. Tactile and vibratory sensation and sense of motion and position were normal. The umbilical reflex was normal. The knee and Achilles reflexes were increased. Plantar irritation caused flexion of the toes on each side. Bladder control was normal.

Ten days after operation she again complained of pain, principally in the right groin and leg. This pain grew progressively worse and became almost continuous; the glands in the groin had enlarged and become hot and tender. By January 10 the pain was much more severe and difficult to control with morphine. A second chordotomy was considered advisable.

Jan. 13, 1922, the posterior spinous processes and laminae of the seventh cervical and first dorsal vertebrae were removed. Bilateral sections of the anterolateral tracts at the level of the first dorsal spinous process were made to a depth of 3.5 mm. Each incision extended from the dentate ligament forward to the exit of an anterior root. Complete relief from pain in the groin and leg was experienced. Neurologic examination showed complete loss of pain and temperature sensations below the area supplied by the sixth dorsal segment on each side. Tactile sensation was unimpaired. The senses of motion and position were preserved. The vibratory sense was normal. Reflexes were unchanged. Tenderness in the Achilles tendons was lost on both sides; motion was preserved. The bladder control was normal at first, but the patient became incontinent as the disease progressed.

The temporary loss of pain and temperature sense with temporary relief of pain must be attributed to trauma without actual division of the spinal fibers involved. Such an injury just mesial to the tracts actually cut seems not only possible but probable.

CASE 5.—Mrs. J. B., aged 48, suffered from pain in the pelvis and legs caused by carcinoma of the uterus; a bilateral chordotomy was performed.

Two years before admission she first noticed a profuse, foul, yellowish vaginal discharge, occasionally blood stained. There had been frequency of urination, with occasional burning in the bladder region. For the last year, there had been severe bearing down pains with occasional sharp pain in the left lower quadrant and in the legs. In Septembr, 1921, the cervix and uterus were cauterized. Since then the pain in the pelvis and legs had grown steadily worse. Morphine in one-half grain (0.03 Gm.) doses was now required to obtain any relief.

Physical examination showed an anemic, emaciated woman in much pain. The pelvis and lower part of the abdomen were filled with a hard, tender mass. The cervix showed a large ulcerating crater. Neurologic examination was negative. Although this patient was in a poor condition, we felt that chordotomy was justifiable since morphine was failing to give relief.

Feb. 16, 1922, the spinous processes and laminae of the third and fourth dorsal vertebrae were removed. A bilateral section of the anterolateral tracts at the level of the third spinous process (between the fifth and sixth dorsal segments) to a depth of 3 mm. extended from the dentate ligament anteriorly to the exit of the anterior roots.

Pain was immediately and completely relieved in the lower part of the abdomen, pelvis and legs. Morphine was required, however, to relieve pain between the shoulders. One-quarter grain (0.016 Gm.) doses were sufficient whereas one-half grain (0.03 Gm.) had not given relief for the previous leg pains. A neurologic examination revealed that all motion was present but that the leg movements were weaker; patellar and Achilles reflexes were present; plantar irritation caused flexion of the toes; tactile, vibratory, motion and position senses were normal. There was loss of pain and temperature senses below a line 2 inches (5 cm.) below the umbilicus.

The deep part of the incision became infected, possibly through the blood stream from the large abscess in the carcinomatous mass in the pelvis disclosed at necropsy. The patient died from meningitis on the eighth postoperative day. Necropsy showed far advanced medullary squamous cell carcinoma of the cervix uteri, which was infiltrating the bladder wall, the upper third of the vagina and all the tissues in the right side of the pelvis. The sacro-iliac plexus was infiltrated and surrounded by carcinoma. There were multiple metastases to the pelvic lymph nodes with neoplastic infiltration of the right psoas muscle; a large abscess in the carcinomatous mass on the right; early vegetative mitral endocarditis and meningitis.

CASE 6.—Mrs. C. B., aged 48, had pain due to metastasis of a breast carcinoma to the fourth lumbar vertebra; a bilateral chordotomy was performed, and was repeated because of failure to relieve pain at the first operation.

The patient had had a radical amputation of the left breast eight months before admission. A month later, pain developed in the right hip and leg which steadily grew worse and for the last five weeks had been continuous, confining the patient to bed. It was described as sharp and shooting in the right hip and as a severe burning in the right leg. Recently, shooting pains had occurred in both legs. Morphine had given little relief. The patient had lost 20 pounds (9 Kg.)

in the last six weeks. Roentgen-ray examination showed destruction of the right lower portion of the fourth lumbar vertebra, evidently from a metastatic growth.

The patient was emaciated, and held the back more or less rigidly because of extreme pain in the lumbar region on motion. The liver was definitely enlarged, hard and sensitive. The lower part of the spine was tender on pressure. There was some enlargement of the sacrum which was very sensitive. There was marked enlargement of the trochanter of the right femur. Neurologic examination was negative except for marked hyperesthesia of the right leg. Touching both legs with a piece of cotton gave the sensation of cold.

Sept. 9, 1922, the posterior spinous processes and laminae of the third, fourth and fifth dorsal vertebrae were removed. Bilateral section of the anterolateral tracts at the level of the fourth spinous process (seventh dorsal segment) was made to a depth of 3 mm. This incision extended from the dentate ligament to the emergence of an anterior root.

No relief was experienced, the pain in the hip and leg remaining unchanged. Neurologic examination showed normal tactile, vibratory, motion and position senses. The pain and temperature senses were lost only in the distribution of the great sciatic nerve on each side. Outside these areas there was no appreciable disturbance in recognition of temperature changes nor in the reception of painful stimuli. The deep and superficial reflexes were unchanged. There was no paralysis. Bladder control was normal.

No other explanation was suggested for failure to produce analgesia and thermanesthesia to a much higher level than the possibility that the spinal cord in this patient was slightly larger than the average and the pain and temperature fibers lay more than 3 mm. from the surface. We now believe that the incision should have been extended mesially through the anterior root.

Not disheartened by the previous failure, the patient begged for a second operation in the hope that she might obtain relief. It was decided to divide the cord to a greater depth, even though motor weakness resulted as this seemed preferable to her present condition. September 25, the posterior spinous processes and the laminae of the sixth and seventh dorsal vertebrae were removed, and bilateral division of the anterolateral tracts was made at the ninth dorsal segment. On the left, the section extended from just posterior to the dentate ligament forward to the exit of an anterior root and to a depth of 4 mm. A similar incision, but to a depth of 3.5 mm., was made on the right.

The pain in the hip and legs was completely relieved. Catheterization was necessary except when micturition was involuntary. Tactile, vibratory, motion and position senses were normal. Pain and temperature senses were lost on the right below a line approximately 2 inches (5 cm.) below the umbilicus (between the areas supplied by the tenth and the eleventh dorsal segments). On the left, analgesia and thermanesthesia were present below the eleventh dorsal distribution. There was complete motor paralysis in both legs until the eleventh day when some motion returned. The patellar reflexes were absent.

Three days after operation, the metastatic areas on the sacrum and great trochanter were broken down, forming deep ulcers, which, however, were non-painful. Although comfortable and relieved of all pain except for a new complaint, pain in the jaw, she failed rapidly and died the twelfth day postoperative.

Necropsy showed metastatic adenocarcinoma from the breast to the liver, the mediastinal, bronchial, suprapancreatic and retroperitoneal lymph nodes, the suprarenals, the lumbar vertebrae, sacrum and femur; a primary medullary squamous cell carcinoma in erosion of the cervix; multiple leiomyomas of the uterus; papilliferous adenoma of the left kidney; multiple emboli and hemorrhagic infarctions of the lung, and subacute spinal pachymeningitis.

Had we realized the extent of the metastasis we probably would not have considered operation in this case. Before the necropsy, however, it seemed justifiable. In the light of our present knowledge, we would not have started the section of the anterolateral tracts so far posteriorly but would, on the other hand, have carried the incision deeper in the anterior portion, actually dividing an anterior root at the exit. It is possible that this would not have actually destroyed all the pain fibers in this particular case as spinal cords vary in size, even at the same level.

CASE 7.—E. U., a girl, aged 16 years, had pain in the back and legs due to a sarcoma of the left leg with spinal metastases; a bilateral chordotomy was performed.

Pain began in the left leg three years before admission. One year before admission, the left leg was amputated for an alveolar round cell sarcoma. The pain had grown steadily worse and now involved the right leg and lower part of the back. It was sharp and shooting in character and almost constant, but was made much more severe by any motion of the leg. Although the left leg had been amputated, she still felt the pain radiate down it. Morphine had been required for several months but recently the pain had been so excruciating that one-half grain (0.03 Gm.) of morphine hypodermically gave practically no relief. Deep roentgen-ray therapy had given no results.

Neurologic examination disclosed a poorly nourished girl, evidently in great pain. The right eye was blind, probably from orbital metastasis. The left leg was amputated. The right patellar reflex was normal. The tendon of Achilles reflex was not obtained. There was no motion of the toes on plantar irritation. The senses of motion and position were not reliable. The vibratory sense in the ankle was normal. There was marked weakness in all the movements of the right leg and toes. Tactile sensations and pain from a pin point were felt normally but the patient stated that the sole of the foot felt "numb" to a pin point. Because of the excruciating pain, which was no longer relieved by morphine, a chordotomy was recommended. This was with the full understanding that the patient's condition was poor and that she might die from the malignancy at any time. Her condition was so pitiful that any one seeing her and knowing that it was almost impossible for her to obtain any sleep would have felt that operation was justifiable

Feb. 21, 1923, a laminectomy was performed, with removal of the posterior spinous processes of the second, third and fourth vertebrae and of the laminae of the third dorsal vertebra. Section of the anterolateral tract to a depth of 2.5 mm. on the right and 3 mm. on the left was made.

She was immediately and completely relieved of the terrible pain in the lower back, right leg, and that referred to the amputated leg, but had considerable pain in the chest. There was complete loss of pain and temperature sensations on the right side downward from a line about 2 inches (5 cm.) below the umbilicus (approximately the eleventh dorsal level). On the left, there was marked impairment in the recognition of painful stimuli but not a complete loss. The temperature sense was lost below the twelfth dorsal level on the left. Tactile sensations were normal throughout. The motion was the same as before operation. The right patellar reflex was normal. Catheterization was necessary except when the patient had involuntary micturition. She had had a septic temperature for some time before operation. After chordotomy the fever remained about as before for

several days; the incision then appeared infected for the first time. No attempt at healing was in evidence when the superficial part of the wound was opened. No symptoms of meningitis developed but death took place on the eleventh day postoperative. Necropsy showed a fibrinopurulent meningitis; multiple infarcts of the brain; multiple metastases of an alveolar round cell sarcoma in the cranial bones, dura mater, lungs, pleura, mediastinum, heart muscle, bronchial and retroperitoneal lymph nodes.

It is questionable whether this death was due to the beginning meningitis. There were no meningeal symptoms and adequate cause for death from metastases was evident. Operation probably hastened the end, but did make the last few days more comfortable.

Case 8.—R. H., a man, aged 40, had pain due to spinal metastasis from adenocarcinoma of the bronchus; a bilateral chordotomy was performed.

His present trouble started a year ago with pain in the right hip. This gradually extended down posterior to the right thigh and calf and was made worse when the patient moved or bent forward. Flexion of the leg gave relief. Six months later, he developed a similar pain in the left thigh and leg. The pain now was practically constant; he took as much as 3 grains (0.19 Gm.) of morphine at a time.

Physical examination was essentially negative except for atrophy of the right lower extremity. Neurologic examination showed increased patellar and Achilles reflexes; an abortive ankle clonus on both sides; no sensory changes. Roentgen-ray examination showed metastases in the fifth lumbar vertebra, in the upper portion of the sacrum and in the region of the left sacro-iliac joint. A dense mass was also seen at the hilum of the left lung.

The pain was severe in both legs, morphine giving only partial relief. Some pain was felt in the chest. Deep roentgen-ray therapy to the chest and lumbosacral region failed to give any relief. Accordingly, chordotomy was advised.

May 28, 1923, a laminectomy was performed with removal of the posterior spinous processes and laminae of the fourth and fifth dorsal vertebrae. Very extensive adhesions between the pia and the arachnoid and to a somewhat less extent to the dura, were found. The spinal cord was yellowish and very stiff as if infiltrated, making rotation difficult. The arachnoid could not be separated from the pia; neither could the attachment of the dentate ligament to the cord be exactly determined. The anterior and posterior nerve roots were adherent to the pia, making it almost impossible in the mass of adhesions to distinguish their exact points of emergence. The knife was inserted at a point approximately halfway between what was considered the points of emergence of the anterior and the posterior roots. The incision was carried to a depth of 3 mm. and forward to the exit of an anterior root. A similar section of the cord was performed on the opposite side.

Following the operation the patient was completely relieved of pain in the legs but complained of considerable pain in the chest. This increased in severity for a time, requiring daily doses of morphine. The chest pain practically disappeared about three weeks after the operation but recurred later, requiring frequent hypodermic injections. Neurologic examination showed complete loss of both pain and temperature senses up to the level of the eleventh dorsal segment. Motor function in both legs was completely lost at first but gradually returned so that he was able to get into a wheel chair four weeks later; however, he never got back sufficient strength to walk. The knee and tendon of Achilles reflexes were

markedly increased as before the operation. Tenderness in the Achilles tendon was lost. There was no change in the tactile, vibratory, motion or position senses. The patient had been catheterized before operation and this had to be continued. He gradually grew weaker and died, July 7. Necropsy disclosed a primary medullary adenocarcinoma of the bronchus of the upper lobe of the left lung. There were metastases throughout the left lung and in the bronchial, mediastinal, lower cervical, prevertebral and retroperitoneal lymph nodes, in the right lung, liver, lower lumbar vertebrae and sacrum.

While chordotomy gave this man complete relief from unbearable pain in the legs, it should not have resulted in the motor weakness noted. Possibly this motor loss would have disappeared had the patient survived for a longer period. He was confined to bed before the operation so was not, in his opinion, made worse by the paralysis of the legs. As the exact location of the dentate ligament could not be determined, it is probable that the incision was made too far posteriorly.

Case 9.—S. R., a man, aged 24, had traumatic sciatic neuralgia associated with partial avulsion of the lumbosacral plexus; a unilateral chordotomy was performed.

The patient was well until two months before admission when he was run over by a farm tractor. The right hip was dislocated but no other injury to the soft parts or bone was discernible. The dislocation of the hip was immediately reduced but he had been unable to walk since because of excruciating pain on movement of the right leg. This developed three or four days after the accident and was described as a constant, severe burning, associated with sharp, stabbing pains. It was confined to the lower right leg and foot. The latter was so hypersensitive that he could not bear the weight of a sheet on it. Touching the foot markedly aggravated the pain.

Physical and neurologic examinations were negative except that there was some atrophy of the glutei muscles and the right great trochanter was more prominent than the left; there was some limitation on extension of the right hip; there were atrophy of the muscles of the right lower leg and atrophic changes in the skin on the dorsum of the right foot. Pain in the popliteal space prevented extension of the right leg at the knee beyond a right angle. The calf of the leg was tender on pressure and all the voluntary movements at the right ankle joint were lost. He could not extend the toes but could flex them slightly. Some sense of motion and position was lost in the right toes. A tuning fork vibration caused pain in the right ankle. Tenderness on pressure was noted along the right sciatic nerve. There was lost tactile sensation and marked hyperalgesia over the dorsum of the right foot and the external surface of the leg about halfway to the knee. The tactile sense was practically lost and the pain sense was greatly increased over the plantar surface of the right foot (fig. 5). There was evident continuous pain in the right foot and the lower leg.

This boy was completely incapacitated and suffering severely. Morphine given hypodermically had been required three or four times daily. The lesion evidently was in the lumbosacral plexus. A unilateral chordotomy seemed to offer the best measure of relief. The only alternative procedure was rhizotomy of the posterior roots.

July 6, 1923, the posterior spinous processes and the laminae of the fourth and fifth dorsal vertebrae were removed. The left anterolateral column was divided between the dentate ligament and the anterior roots at the level of the fourth dorsal spinous process (the seventh dorsal segment). The incision just in front of the attachment of the dentate ligament extended to a depth of 3 mm.

The postoperative convalescence was satisfactory. The pain was immediately relieved in the leg and foot. The day following operation, he was able to extend

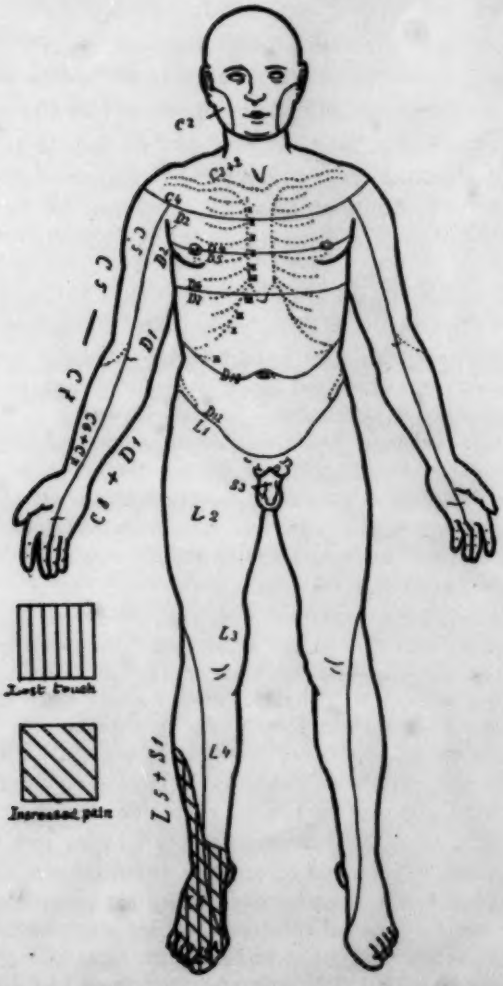

Fig. 5 (case 9).—Areas of lost touch and increased pain before operation when there were tactile anesthesia and hyperalgesia with excruciating pain in right leg.

the right leg at the hip and the knee; this had been impossible before because of induced pain. On the eighth day he was up and around in a wheel chair with a shoe on for the first time since the accident. The bladder control was not affected.

A neurologic examination, July 16, showed no change in the muscles previously paralyzed. All other movements were normal. No limitation was noted in the

extension of the leg. The tendon of Achilles tenderness was lost on the right, and the sense of motion and position of the toes was lost on the right. There were analgesia and thermanesthesia below a line around the thigh about 4 inches (10.1 cm.) above the right knee (fig. 6). The tactile sensation was lost over the same area as before. The vibratory sense was considerably diminished at the right ankle. All the tendon reflexes were normal except for the lost right Achilles

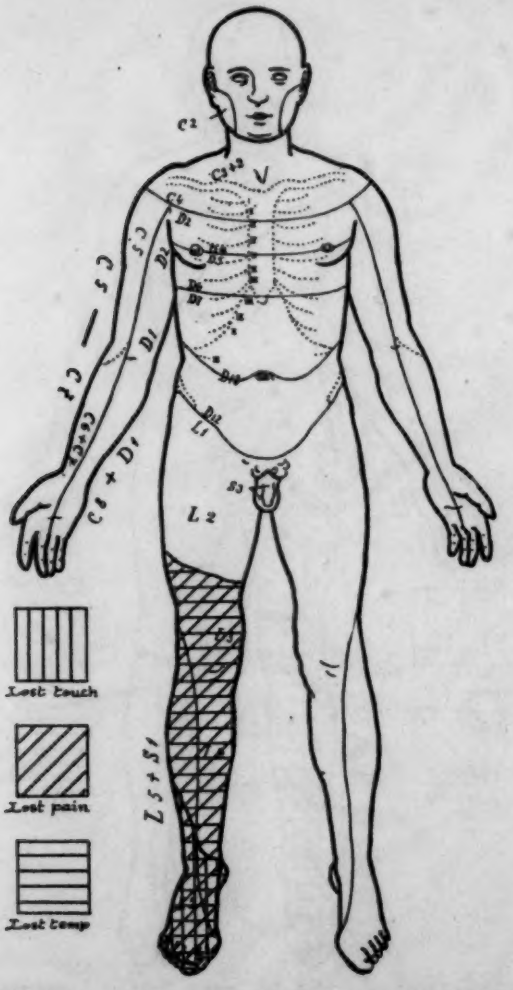

Fig. 6 (case 9).—Areas of lost touch, pain and temperature ten days after section of left anterolateral tract at seventh dorsal segment; depth, 3 mm.; complete relief of pain.

tendon reflex. Plantar irritation caused flexion of the toes on the left; there was no movement on the right.

A letter, November 16, stated that he had the sensation as of a swarm of ants running over the right foot when he lay down and that he wore an overshoe rather than a regular shoe because the foot "seemed sore."

He returned for examination, Feb. 26, 1924, reporting that he had been able to do some work, had gained 40 pounds (18.1 Kg.) in weight and was quite comfortable. Neurologic examination showed atrophy of the right glutei muscles and of the muscles of the right leg. All the tendon reflexes were normal except the lost Achilles tendon jerk. Foot drop still was present. Analgesia and thermanesthesia were present below a line about 3 inches (7.6 cm.) above the right

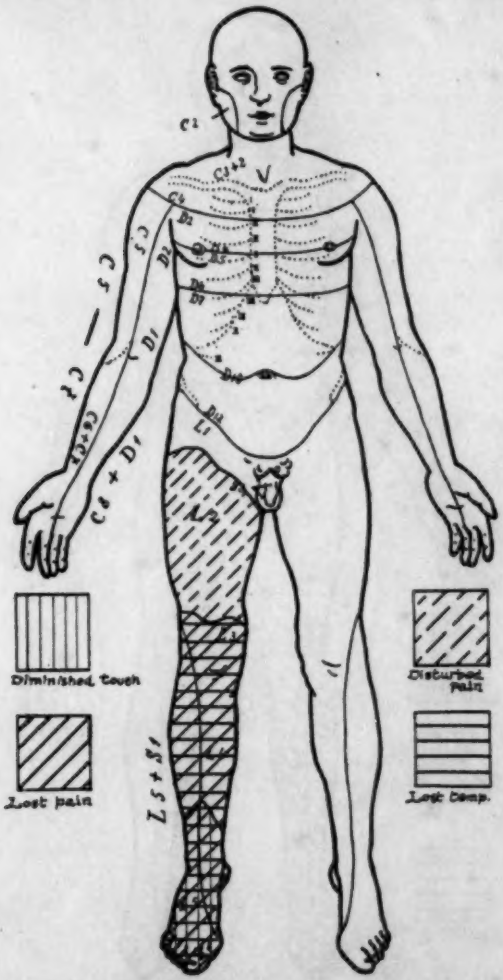

Fig. 7 (case 9).—Areas of diminished touch, lost and disturbed pain and lost temperature eight months after left chordotomy, 3 mm. deep at seventh dorsal segment.

knee. The tactile sense was lost or greatly diminished in the foot and ankle as before. Above the area of lost pain and temperature sense was a band extending nearly to the groin in which the pain sense was preserved, but not normal, a pin point being felt as a flat knife edge (figs. 7 and 8).

The last report, May 18, 1924, stated that the atrophy previously noted was progressing. Apparently no pain was felt. He expressed great appreciation for the relief afforded him.

Fortunately the pain in this case was referred only to the lower part of the leg and foot. Had the pain been in the lower back or pelvis, complete relief would not have been obtained; this, in spite of the fact that section of the anterolateral column was made at approximately the seventh dorsal segment. We now believe that the fibers

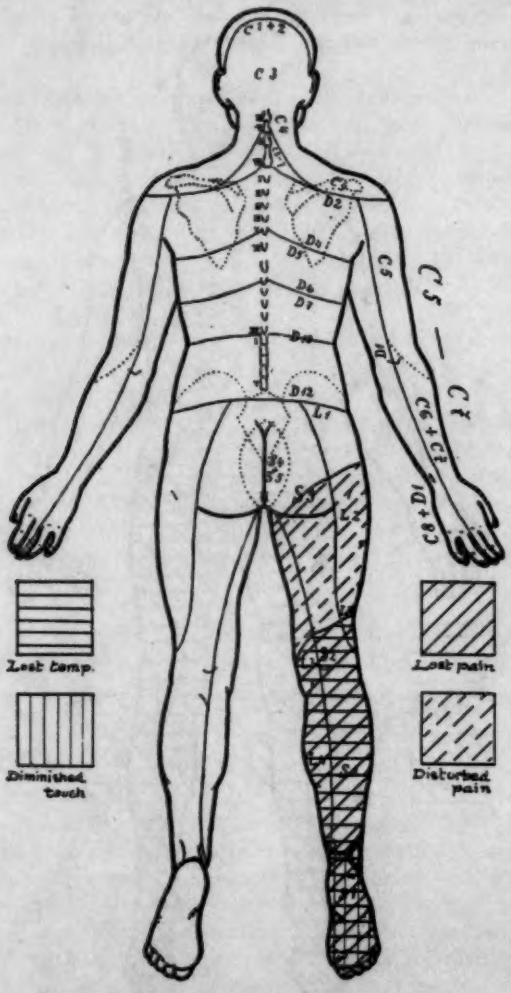

Fig. 8 (case 9).—Back view of patient.

carrying pain and temperature sensations from the thigh and lower abdominal region lie more anteriorly and mesially than those from the lower leg and foot. Had the section been made deeper at the emergence of the anterior root, the area of analgesia would have been much higher.

CASE 10.—Mrs. C. B., aged 28, suffered pains in the pelvis and legs from carcinoma of the uterus; a bilateral chordotomy was performed.

The present trouble began nine months before admission with shooting pains down both legs. Carcinoma of the cervix was treated with radium and the pains were relieved. The pain returned a month later but was again relieved by radium. For the last four months there had been steady pain in the groin and for one month, in the legs. After the radium treatments, the patient had a curettage and deep roentgen-ray therapy. Morphine in increasing doses had been required and now did not control the pain.

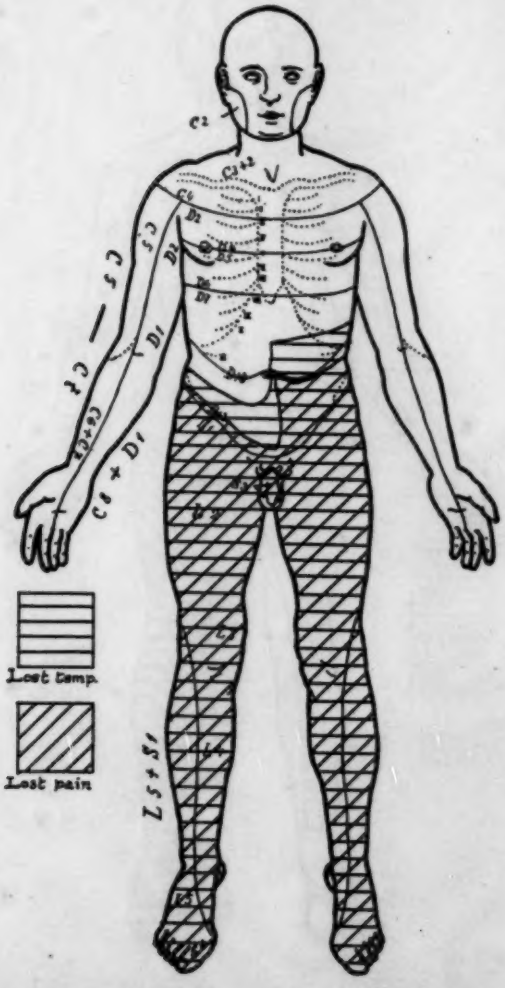

Fig. 9 (case 10).—Areas of lost temperature and pain four days after bilateral chordotomy, 3 mm. deep, at sixth dorsal segment; complete relief of pain; difference in levels of analgesia and thermanesthesia should be noted.

Physical and neurologic examinations were negative except for extreme weakness and the extensive carcinoma of the uterine cervix with pelvic metastases. A chordotomy was advised because of excruciating pain in the lower back, pelvis and both legs, uncontrolled by morphine.

Nov. 10, 1923, the posterior spinous processes and laminae of the third and fourth dorsal vertebrae were removed. A bilateral chordotomy at a level about midway between the laminae of the third and fourth dorsal vertebrae divided the anterolateral tracts in the sixth dorsal segment. The incisions extended 3 mm. in depth just in front of the dentate ligaments and were carried forward to the anterior roots.

She was completely relieved of pain, but immediately after the operation she had marked weakness in the muscles of both legs; the toes, however, could be moved normally. Urination was involuntary but the patient knew when she was urinating.

Neurologic examination, November 14, by Dr. Camp, showed that the patient could make all the movements of both legs with some incoordination. The umbilical, patellar and Achilles tendon reflexes were lost. Plantar irritation caused flexion on the right, extension on the left. The pain sense was lost below the inguinal region on the right and below the umbilicus on the left. The tendon of Achilles tenderness was lost on both sides. The temperature sense was lost to a higher level than the pain sense; it was lost on the left to halfway between the umbilicus and the inguinal region, and on the right to a level about 3 inches (7.6 cm.) above the umbilicus (fig. 9). The senses of motion, position and localization were preserved; tactile and vibratory sensibilities were normal.

December 17, the patient was completely free from pain, but still weak from additional uterine hemorrhages. The knee and Achilles tendon reflexes were present on the left, absent on the right. The patient could flex the right thigh but not extend it. The left leg movements were normal. Plantar irritation caused extension on both sides. The senses of motion and position were normal; the vibratory sense was lost in the ankles. The tendon of Achilles tenderness was lost. The tactile sense was normal. The area of analgesia extended to just above the inguinal line on the right and to 2 inches (5 cm.) below the umbilicus on the left.

The motor weakness must have been due to encroachment on the crossed pyramidal tracts just posterior to the dentate ligament. A point of interest was the difference in levels of analgesia and thermanesthesia, the latter being at least one segment higher.

Case 11.—Mrs. M. A., aged 34, had pain due to carcinoma of the cervix; a bilateral chordotomy was performed.

The present trouble began a year before admission following a miscarriage. The patient immediately had a profuse, foul, sometimes blood stained vaginal discharge, which had persisted. Backache and burning and itching around the vagina soon developed. The pain had increased in intensity and was confined largely to the lower part of the abdomen, at times passing down both legs. She had had actual cauterization of the cervix and uterus followed by deep roentgen-ray therapy; this had stopped the uterine hemorrhages but had not influenced the pain. The pathologic diagnosis was far advanced medullary squamous cell carcinoma of the cervix.

Physical examination was essentially negative with the exception of the extensive crater in the cervix and uterus with pelvic extension and metastases. A neurologic examination was negative. A chordotomy was advised.

Nov. 24, 1923, the posterior spinous processes and the laminae of the fourth and fifth dorsal vertebrae were removed, and bilateral section was made of the anterolateral tracts at the level of the seventh dorsal segment (between the fourth

and the fifth spinous processes). The incisions were made to a depth of 3 mm., just in front of the reflection of the dentate ligament, and were carried outward and forward, emerging at an anterior root on each side.

The patient was completely relieved of pain. A neurologic examination by Dr. Camp, November 28, showed no motor weakness in the extremities. The knee and Achilles tendon reflexes were normal. Plantar irritation caused flexion of the toes on each side, and there was a lively tickle sense on both sides. The senses of motion and position were normal. The tendon of Achilles tenderness was lost on both sides. Sensation to a pin point was variable. It was felt acutely in spots and was entirely absent in surrounding spots. Both plantar surfaces were completely analgesic in spite of which the tickle sense was preserved. The loss of the pain sense while incomplete extended to the umbilicus. The patient differentiated heat and cold normally over the abdomen, in the right leg and on the outer side of the left thigh. The thermal sense was completely lost on the inner side of the left thigh and below the knee. The tactile sense was normal. She stated that her pain was entirely relieved by the operation.

Feb. 21, 1924, the patient was free from pain. The results of the neurologic examination were practically the same. A letter, March 7, 1924, stated that severe pain had developed throughout the back, especially sharp in the lumbar region, radiating to the right hip, and that she was growing much weaker and was no longer able to be about. It is possible that this new pain was due to metastases at a higher level, especially since the pain was referred higher in the back than before.

Case 12.—H. P., a man, aged 24, had pain due to sarcoma of the femur; a bilateral chordotomy was performed, and the second and third operation, the last combined with rhizotomy.

This young man entered the hospital because of excruciating pain in the left leg and the right orbit. He first noticed pain in his left hip one year before admission. The pain was piercing and sharp in character, and worse when he was using the leg. It had steadily grown more severe, involving both legs and was now practically constant, requiring morphine in large doses. Examination revealed a right exophthalmos, apparently due to a metastasis in the posterior part of the orbit. A large fusiform swelling of the left thigh was shown by roentgen-ray examination to be a periosteal sarcoma involving the upper third of the femur. A neurologic examination was negative. Roentgen-ray therapy relieved pain in the right eye, but had no influence on the pain in the legs.

Nov. 24, 1923, a laminectomy was performed, with removal of the posterior spinous processes and laminae of the third and fourth dorsal vertebrae. A bilateral chordotomy at the level of the sixth dorsal segment was done. The incisions extended 3 mm. deep and emerged at the exit of an anterior root on each side.

A neurologic examination, November 28, showed the umbilical, cremasteric, patellar and Achilles tendon reflexes normal. Plantar irritation caused flexion on both sides. There was no loss of sense of touch, vibration, motion or position. The tendon of Achilles tenderness was lost on both sides. No pain was felt from a pin prick on the outer and posterior aspects of both legs from just below the knee to the sole of the foot. The patient made frequent mistakes in discriminating between a pin point and a pin head below the knee on the left. On the right leg, he could not discriminate temperature changes up to the groin. No motor impairment was noted.

The patient continued to have pain although morphine was not as frequently required. Examination, December 19, showed practically the same findings as given above. The analgesia is shown in figures 10 and 11. Roentgen-ray therapy continued to relieve the pain in the head but not in the legs. Accordingly, a second chordotomy was performed.

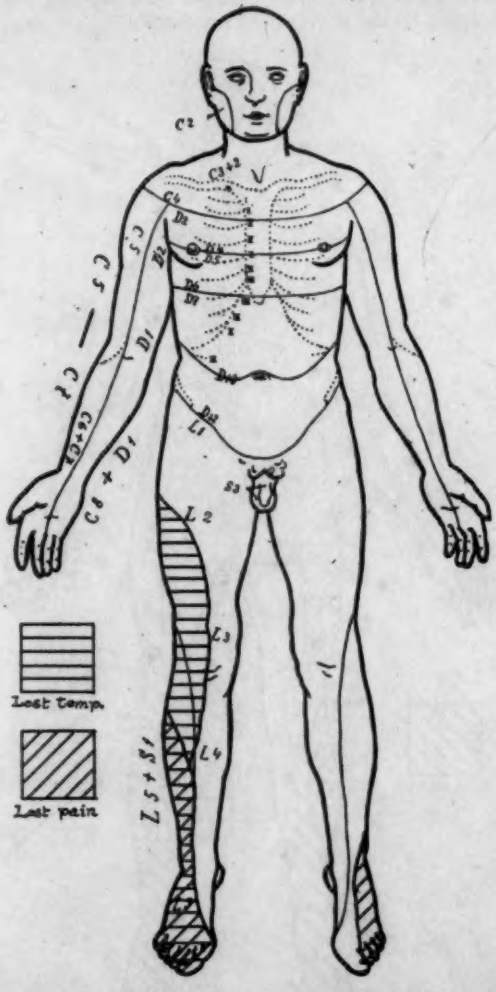

Fig. 10 (case 12).—Areas of lost temperature and pain twenty-one days after bilateral chordotomy, 3 mm. deep, at sixth dorsal segment; section extended to lateral side of motor root; second chordotomy 3 mm. deep at level of third dorsal segment made no further change in sensory findings.

December 20, a second laminectomy was performed, with removal of the posterior spinous processes and the laminae of the first and second dorsal vertebrae, and a bilateral chordotomy was done at the level of the third dorsal segment. The incision on either side extended to a depth of 3 mm. and emerged at an anterior root.

A neurologic examination showed no change from the findings after the first chordotomy. The patient still complained of pain, especially in the region of the tumor and in the chest. However, morphine was not as frequently required and many times he had a good night after taking acetysalicylic acid and barbital. The tumor grew rapidly and, in the latter part of January, the pain increased in severity again. He begged for another spinal operation as he felt that he had been somewhat relieved by the previous chordotomies.

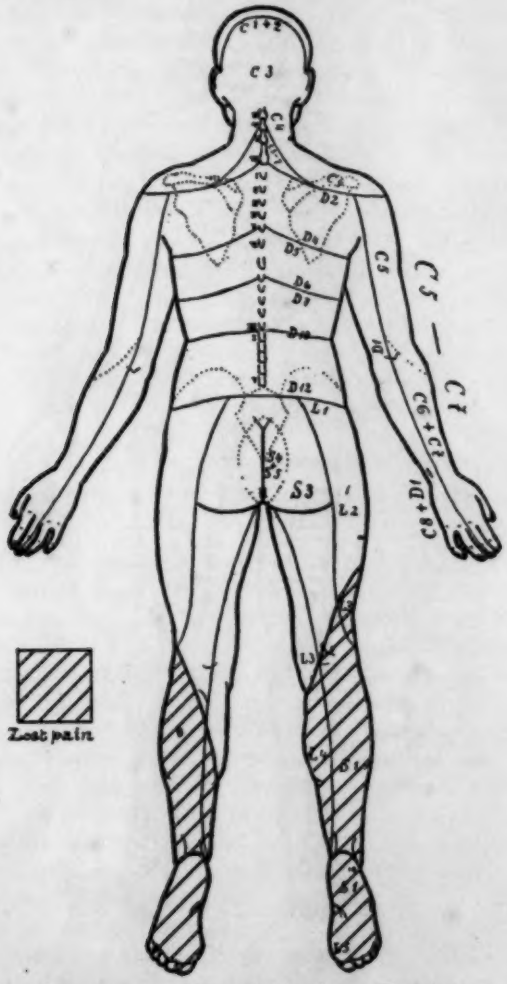

Fig. 11 (case 12).—Back view of patient.

A third operation was performed Feb. 11, 1924. The posterior spinous processes and laminae of the sixth, seventh and eighth dorsal vertebrae were removed and a bilateral chordotomy was performed at the level of the ninth dorsal segment. The knife was inserted to a depth of 3.5 mm. directly medial from the insertion of the dentate ligament and carried forward to the emergence of an anterior root. The posterior roots exposed in the operative field were divided. These were the ninth, tenth, eleventh and the upper fibers of the twelfth thoracic root.

The patient was completely relieved of the pain in both legs and up to about 2 inches (5 cm.) above the umbilicus. He still asked for morphine but after a week of satisfactory sterile hypodermic injections, the nature of his medication was explained and no further hypodermic treatments or morphine by mouth were requested.

A neurologic examination was made, February 23, showing both abdominal, the left knee and both Achilles tendon reflexes lost. There was ankle clonus on

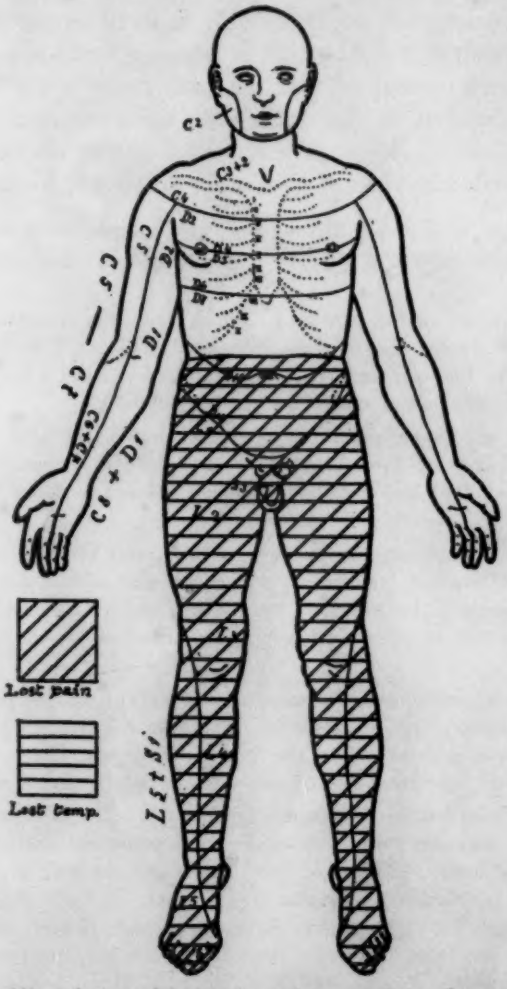

Fig. 12 (case 12).—Areas of lost pain and temperature eleven days after third bilateral chordotomy; section of anterolateral tracts, 3.5 mm. deep, at level of ninth dorsal segment. Because of two previous failures to relieve pain and to insure a higher level of analgesia, bilateral rhizotomy of ninth, tenth, eleventh and upper fibers of the twelfth posterior thoracic roots was combined with the chordotomy; complete relief was given.

the right, a positive Babinski reflex on the left. The tenderness of both the tendons of Achilles was lost. The tactile and vibratory senses as well as those of motion and position were normal in the legs. There was loss of pain and

temperature sense below the eighth dorsal segment (fig. 10). The patient was unable to flex the right ankle; all other motions were preserved.

He remained very comfortable except for a return of pain in the right eye which was immediately relieved by roentgen-ray treatment. Occasional urinary incontinence was noted. He died, April 9, 1924. Necropsy showed primary small spindle cell sarcoma of the left femur with metastases in the cranium, ribs, lungs and pleura, and early bronchopneumonia.

Why this patient was not completely relieved by section of the cord to the usual depth is not clear. It is possible that his cord was somewhat larger than normal or that the pain tracts were less superficial than usual. Division of the tracts only 0.5 mm. more mesially gave complete relief in the legs. The division of the posterior roots was done to insure complete loss of pain in the pelvis and lower abdomen.

CASE 13.—Mrs. M. J., aged 55, had pain in the lumbosacral region and pelvis due to advanced carcinoma of the uterus, for which a bilateral chordotomy was done.

Since an operation on the uterus in August, 1923, she had suffered much pain in both lower quadrants and in the lumbosacral region. The pain was intense, sharp, stabbing in character and frequently rediated upward. Morphine had been required at least three times daily.

Physical and neurologic examinations were negative for present consideration except for far advanced carcinoma of the uterus with extensive pelvic metastases. The patient had had deep roentgen-ray therapy without having the pain relieved, and morphine gave only partial relief.

Jan. 10, 1924, a laminectomy was performed, with removal of the posterior spinous processes and the laminae of the fourth and fifth dorsal vertebrae. A bilateral chordotomy at the level of the seventh dorsal segment was also done. The incision extended to a depth of 3 mm. and anteriorly to the emergence of an anterior root.

Postoperative convalescence was satisfactory. There was no pain in the lower part of the abdomen, the lumbosacral or pelvic regions since the operation. Catheterization was necessary for the first four days. There was some pain in the region of the operation and of the sternum, which lasted only a few days.

A neurologic examination was made January 11. The patient stated that she had none of her previous pain. All motion was preserved except for flexion of the left leg at the knee. She moved both ankles and the toes of both feet. Her sense of motion, position and vibration was normal. A light touch was felt and localized perfectly. The right patellar jerk was normal; the left was not obtained. Neither Achilles jerk was obtained. Tendon of Achilles tenderness was present. Pain and temperature senses were lost on both sides below the umbilicus. Plantar irritation gave no movement on the right, slight flexion on the left.

Examination, January 23, showed both patellar and both Achilles reflexes normal. The abdominal reflex was not obtained. Plantar irritation caused flexion on the right, unquestionable extension on the left. The area of lost pain and temperature was diminished since the first examination; there was now complete loss below the eleventh dorsal segment on the right and on the left below the twelfth dorsal on the median half of the posterior surface of the buttocks and thigh

(sacral 1, 2, 3) and of the leg below the knee (lumbar 4, 5, sacral 1) (fig. 13). She complained of some pain above the iliac crest and anterior to the superior spine on the left. All motion was now normal.

At the time of discharge she had no pain, was gaining and had overcome the morphine habit. Later examination showed no change from the foregoing findings; she was still free from pain.

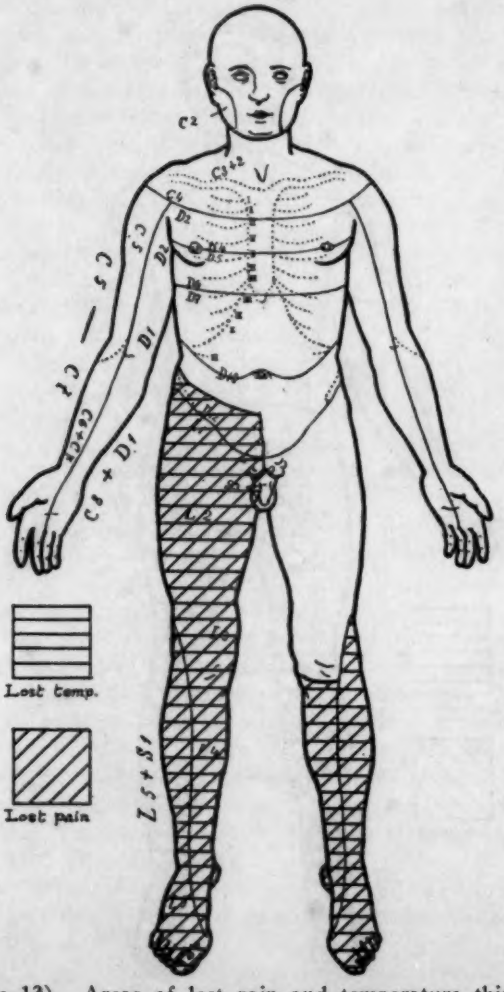

Fig. 13 (case 13).—Areas of lost pain and temperature thirteen days after bilateral chordotomy, 3 mm. deep, in seventh dorsal segment; complete relief of pain. The day after the operation pain and temperature were lost on both sides below the umbilicus. The area of analgesia and thermanesthesia generally diminishes slightly, but this is an extreme example.

Case 14.—Mrs. E. C., aged 60, had pain due to a retroperitoneal neoplasm; a unilateral chordotomy with rhizotomy was performed.

A year before admission she had been operated on for an abdominal tumor, which was not removed. For some time previous to this she had had severe

pains in the left side of the abdomen and lumbar region. A second operation six months before admission showed a large, inoperable tumor, apparently originating retroperitoneally in the left upper quadrant. The pains had grown progressively worse, confining her to bed. They occurred almost constantly and were described as sharp and shooting in character, radiating throughout the left side of the abdomen and lumbar region, sometimes down the left leg.

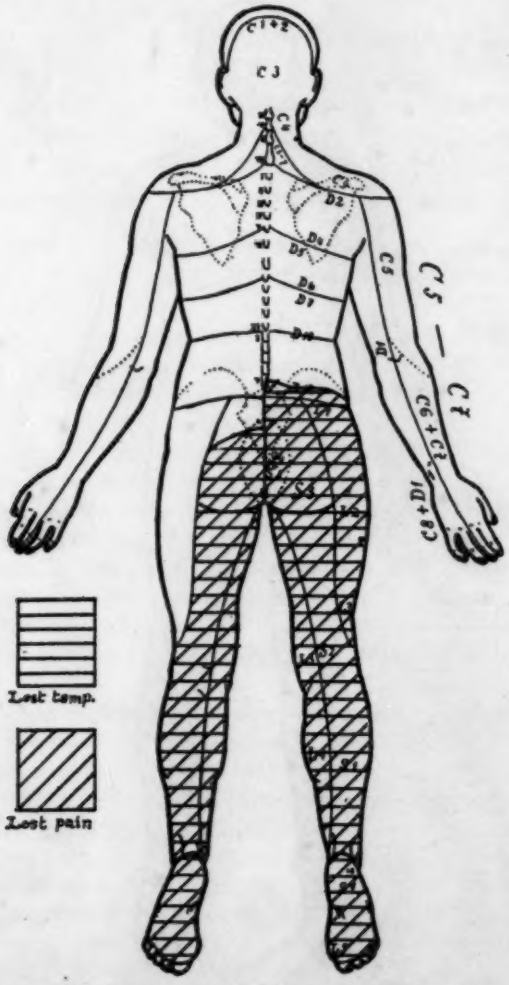

Fig. 14 (case 13).—Back view of patient.

A neurologic examination was absolutely negative. The physical and roentgen-ray examinations disclosed nothing pertinent to this study beyond the large tumor in the left side of the upper part of the abdomen. Deep roentgen-ray therapy gave no relief. Morphine was required constantly and even then did not afford an adequate measure of relief. Chordotomy combined with rhizotomy was therefore advised.

Feb. 8, 1924, a laminectomy was performed with removal of the posterior spinous processes and the laminae of the fifth, sixth and seventh dorsal vertebrae. The right anterolateral tract was divided at the eighth dorsal segment from just anterior to the pial reflection of the dentate ligament to the emergence of an anterior root, the incision being carried to a depth of 3 mm. The sixth, seventh, eighth and ninth posterior roots on the left were divided to insure analgesia slightly above the abdomen.

Postoperative convalescence was satisfactory. There was no pain in the left side of the abdomen, the left lumbar region or the left leg. The patient complained for the first time of some pain in the right side of the abdomen and, for a few days, of pain in the right leg. Catheterization was necessary much of the time although at times she voided naturally.

A neurologic examination, February 26, showed a weakness in the right leg. The left knee jerk was normal, the right markedly diminished. The left Achilles tendon jerk was normal, the right diminished. Plantar irritation caused extension on both sides. The pain sense was lost from just below the nipple line (sixth segment) to the end of the toes on the left. The temperature sense was lost below the tenth dorsal segment. Apparently there was a much wider overlapping of the temperature than the pain fibers in the skin. The tactile, motion, position and vibratory senses were preserved in both legs. The tactile sense was lost in the narrow band above the middle of the abdomen (approximately the eighth segment) on the left. On the right side at about the ninth rib anteriorly was a band of lost pain sensation.

Reports from the patient for several months showed no return of the pain in the left side of the abdomen, the lumbar region or the leg. From time to time she had pain in the right side of the abdomen. We believe that the posterior roots on the right side should have been cut although a bilateral chordotomy was scarcely indicated. Motion in the right leg was gradually improved.

Case 15.—Mrs. M. H., aged 37, had pain in the lower abdomen and back from carcinoma of the uterus; a bilateral chordotomy was performed.

About four months before admission the patient developed pain in the lower part of the abdomen and the lower lumbar region. It had been almost continuous since and was described as sometimes sharp, at other times dull in character. Recently the pain had become extremely severe, referred to the lower part of the abdomen, the lumbosacral region, both hips and legs. Cautery was used three months before admission on the cervix and uterus followed by deep roentgen-ray therapy without relief of symptoms. For three months she had had difficulty in starting urine and considerable dysuria. Morphine in large doses had failed to give relief, so chordotomy was advised.

A neurologic examination was essentially negative. Physical examination showed nothing pertinent except the large ulcerating carcinoma of the cervix with pelvic metastases.

May 2, 1924, a laminectomy was performed, with removal of the posterior spinous processes and the laminae of the fourth, fifth and sixth dorsal vertebrae. The anterolateral tracts were divided at the level of the seventh dorsal segment to a depth of 3 mm. The incision commenced just in front of the dentate ligament and extended to the emergence of an anterior root.

The laminectomy incision healed promptly. The patient was completely relieved of the pain in the abdomen, back and legs and required no more morphine. On one occasion she complained of pain in the legs but this was not severe and lasted only a short time. Catheterization was not necessary.

A neurologic examination showed no loss in the motion of the extremities. The knee and Achilles tendon jerks were normal. Plantar irritation resulted in flexion of the toes. Tactile, vibratory, motion and position senses were normal. There was loss of pain on both sides below a line 2 inches (5 cm.) below the umbilicus (approximately the eleventh dorsal segment). The temperature sense was impaired from the umbilicus to the groin, below which level it was lost on both sides.

The level of complete temperature loss was much lower than of lost pain sensation although the area of diminished thermal sense, in which the patient was occasionally able to distinguish temperature changes correctly, extended to a higher level than the analgesia. This must indicate in this patient a wider overlapping of the thermal sense in the skin, or a much lengthened crossing in the cord.

CASE 16.—Mrs. A. M., aged 58, had pain due to spasmodic contractions of the legs; a bilateral chordotomy was performed.

About four years before admission she developed sudden cramplike pains in the left hip while walking. The leg would draw up causing her to fall. The pain appeared only at long intervals until two years before admission when it occurred almost daily, especially after she relaxed in a recumbent position. The pain gradually increased in severity and frequency, confining her to bed for the last twenty months. For the last year, the right leg had been similarly involved. During the attacks of pain there was forceful, involuntary flexion of the thighs on the abdomen, of the legs at the knees, and of the toes. The pain always radiated from the hips down the posterior aspect of the legs to the heels.

Physical examination was negative except for marked contractures of the legs, the thighs and knees being flexed. Neurologic and spinal fluid examinations were negative. Roentgen-ray examination was negative except for some arthritis of the spine. The pain was so severe that she cried out during attacks. Morphine had been freely used but only partially alleviated her suffering. No cause for the spasmodic contractions and the pain was ever determined. A bilateral chordotomy was finally advised.

Aug. 13, 1924, a laminectomy was performed, with removal of the posterior spinous processes and the laminae of the fourth and fifth dorsal vertebrae. A bilateral section of the anterolateral columns was made to a depth of 3 mm., the incision extending from the dentate ligaments anteriorly into the anterior roots.

Immediate postoperative recovery was delayed because of a pulmonary complication. The day after operation, she said that her legs felt numb. No change was actually noted in the tactile sensation, however, and this subjective sensation had disappeared the next day. Morphine was discontinued. She had to be catheterized until September 10, when she voided normally. She felt no pain in the legs after the operation.

A neurologic examination, August 29, showed loss of the pain sensation below the ninth dorsal segment on the right and the eleventh segment on the left. Temperature was lost below the crest of the ilium on each side. There was an area of diminished sensation to pin point pain on the inner side of the thigh and in the upper gluteal region on the left (figs. 15 and 16). The tendon of Achilles tenderness was lost, and there was no change in the light touch, vibration, motion and position senses. The reflexes and motion were unchanged, except for a tendency to extension of the great toes on plantar stimulation.

A report a year later stated that there had been no return of pain in the legs although the spasmodic movements still persisted.

CASE 17.—Mrs. A. D., aged 31, had intractable pain due to carcinoma of the uterus; a bilateral chordotomy was performed.

The patient first noted a yellowish, blood streaked, foul vaginal discharge fifteen months before admission. Five months later the cervix was amputated and radium was applied. The carcinoma continued to grow. Later, cauterization was done and deep roentgen-ray therapy instituted without evident benefit. The patient now had extensive metastases and excruciating pain in the lower part of the abdomen and both legs. A neurologic examination was negative.

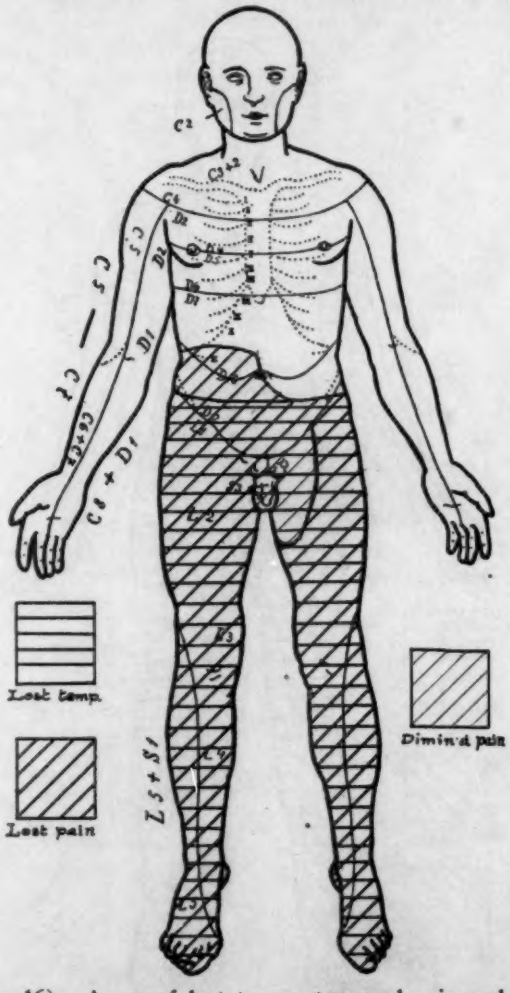

Fig. 15 (case 16).—Areas of lost temperature and pain and diminished pain sixteen days after bilateral section of anterolateral tracts at seventh dorsal segment; incisions were made 3 mm. deep and extended anteriorly into respective anterior roots. Complete relief of pain resulted and no motor weakness. The level of lost pain sensation is higher than that of temperature loss; there is also an area of diminished pain perception on left thigh and right lumbar region.

Dec. 12, 1924, a laminectomy was performed, with removal of the posterior spinous processes and the laminae of the fifth, sixth and seventh dorsal vertebrae. A bilateral chordotomy was done at the level of the fifth spinous process (through

the eighth dorsal segment). The incision, just anterior to the dentate ligament, extended to a depth of 3 mm., circled forward and outward, emerging at an anterior root.

The postoperative convalescence was satisfactory. Catheterization was necessary for the first three days. She was much more comfortable, the chief complaint being pain in the region of the incision. During the day, she was practically completely relieved but nearly every night she required one-fourth grain

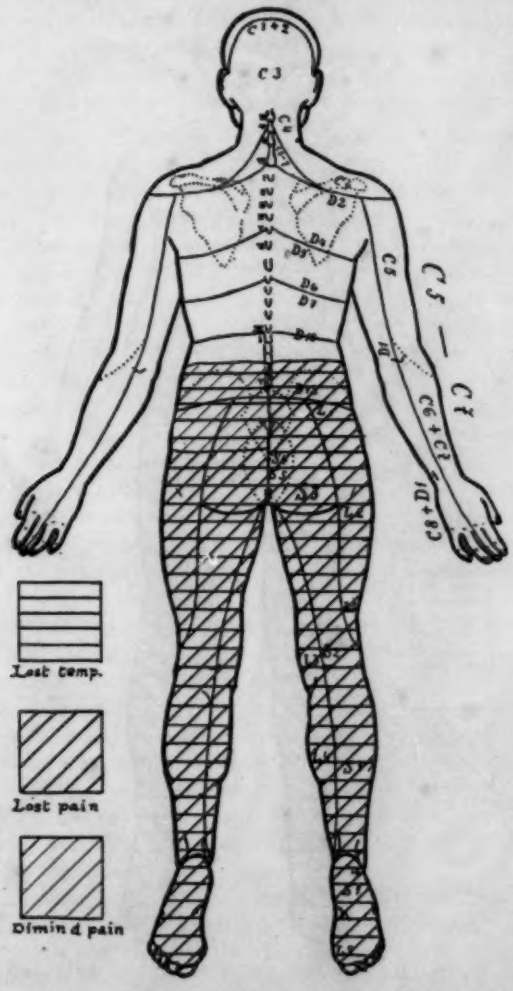

Fig. 16 (case 16).—Back view of patient.

(0.016 Gm.) of morphine, usually for pain in the back and sometimes in the legs. She was much brighter and more cheerful than before operation.

A neurologic examination, December 22, showed normal umbilical, patellar, Achilles and plantar reflexes on both sides; motion, position, vibratory and tactile senses were normal. The temperature sense was not certain up to the groin on each side but was correct in interpretation more often than wrong. A pin point

was not distinguished as such over the anterior and lateral aspects of the right leg and the dorsum of the foot, and a pin point was not felt as painful in many places up to the groin. This loss was not segmented but appeared in irregular areas.

We can offer no explanation for the failure in this case to get a greater loss both of temperature and pain perception. The relief was

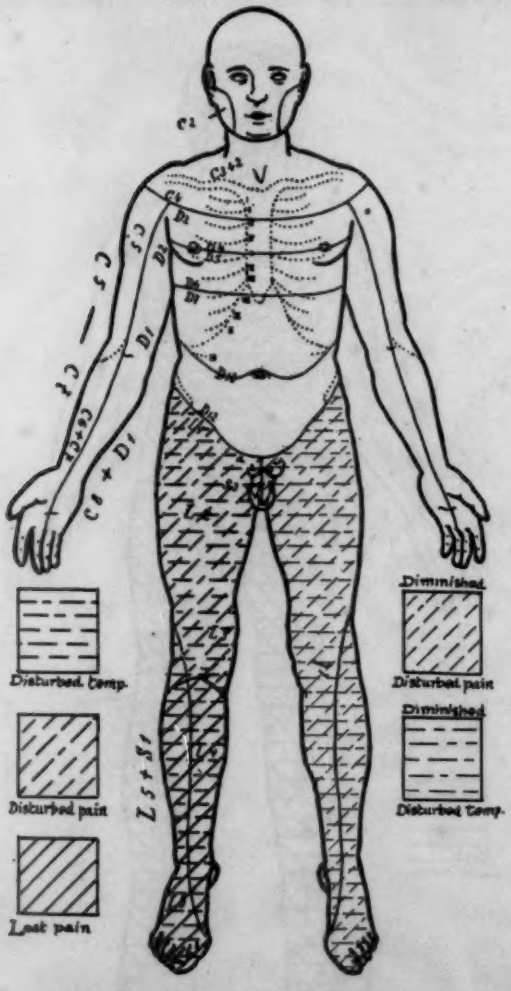

Fig. 17 (case 17).—Areas of temperature and pain ten days after bilateral chordotomy, 3 mm. deep, in eighth dorsal segment; relief of spontaneous pain much greater than area of complete analgesia would indicate; on left, pain and temperature senses were disturbed but not as markedly as on right thigh.

more marked than would be expected from the neurologic findings. This relief, however, was not constant and at times the patient complained of severe pains in the legs.

Case 18.—Mrs. B. W., aged 35, had pain in the abdomen, lower back, rectum and legs, for which a chordotomy was done.

For the last three months she had had constant, severe, aching pains in the back, rectum, across the lower part of the abdomen and down both legs to the knees. In January, 1923, amputation of the cervix was done; in January, 1924, hysterectomy; in August, 1924, actual cautery to a growth in the upper part of the vagina; in November, 1924, radium therapy in the vagina, and in December, 1924, deep roentgen-ray therapy. The diagnosis was carcinoma of the cervix with

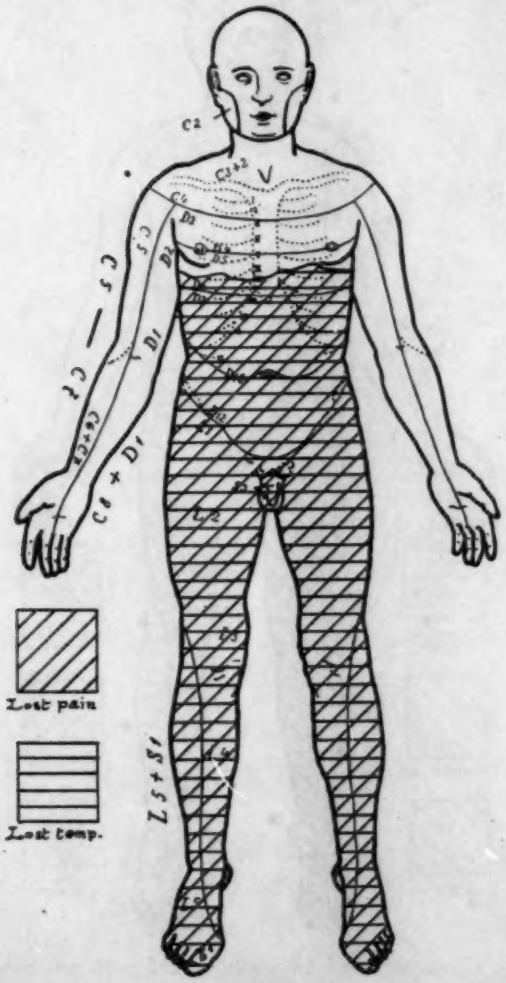

Fig. 18 (case 18).—Areas of lost pain and temperature five days after bilateral chordotomy between fifth and sixth dorsal segments; section of each anterolateral tract to a depth of 3 mm. at dentate ligament and anteriorly through to the mesial side of the exit of an anterior root, which gave the highest level of analgesia and thermanesthesia obtained in any case; no change in motor function, tactile, vibratory, motion, position and deep pressure sensations or in cutaneous and tendon reflexes; complete relief of pain.

pelvic metastases. Since the radium therapy the patient had had difficulty with urination. The pain was now so severe that sleep was not possible even with morphine.

A neurologic examination was negative. A physical examination was negative except for a mass in the pelvis and tight stricture in the vagina. A chordotomy was advised.

Feb. 5, 1925, a laminectomy was performed, with removal of the posterior spinous processes of the third, fourth and fifth and the laminae of the third and

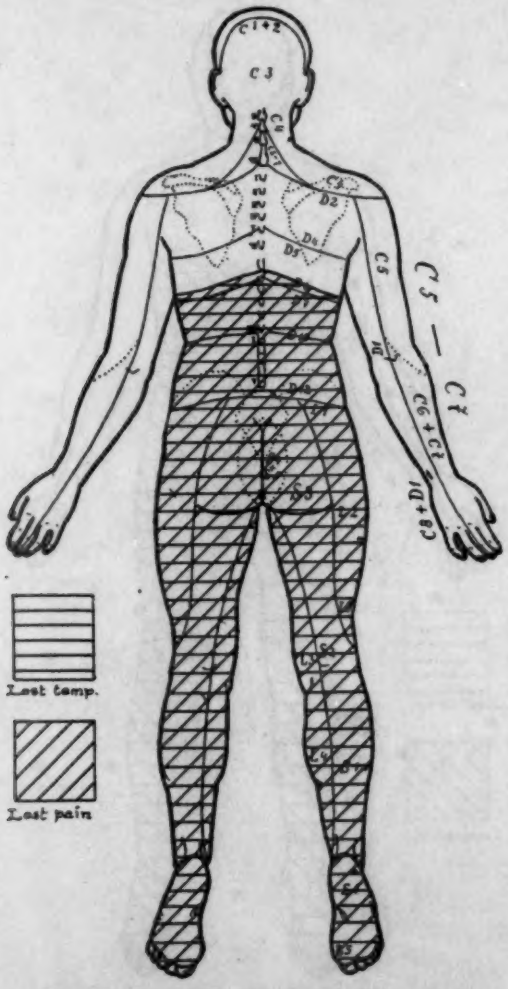

Fig. 19 (case 18).—Back view of patient.

fourth dorsal vertebrae. Section was made of the right anterolateral tract to a depth of 3 mm. at the level of the third posterior spinous process; i. e., the fifth or sixth dorsal segment. The incision was started close to the anterior surface of the dentate ligament and carried anteriorly through the emergence of an anterior root. As a rule, we have not carried the incision quite as far medially, the knife usually emerging at the lateral rather than the mesial side of the motor root. A similar division of the left anterolateral tract was made.

She was completely relieved of pain in the back, pelvis, rectum and legs. Catheterization was not necessary; she was incontinent at times. Morphine was gradually withdrawn and discontinued entirely after the fifth day although she had required large doses before the operation.

A neurologic examination, Feb. 10, 1925, showed all motion in the lower extremities to be normal. The patellar and Achilles tendon reflexes were normal. Plantar irritation caused flexion on the toes on both sides. The vibratory sense was present at the ankles, the tibiae and the patellar and iliac crests. The senses

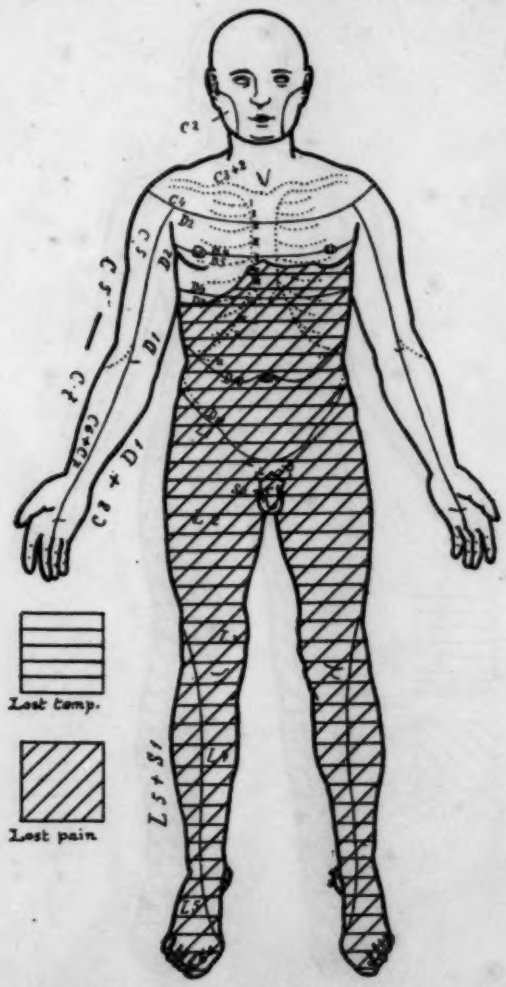

Fig. 20 (case 18).—Areas of lost temperature and pain twenty-nine days after bilateral chordotomy, showing lower level of analgesia and thermanesthesia than was present five days after operation, as shown by figures 18 and 19.

of motion and position were normal. Deep pressure was felt as such, but continued pressure caused no pain. The tendon of Achilles tenderness was lost. The tactile sense was normal. The pain and temperature senses were lost on both sides below a line approximately halfway between the areas supplied by the fifth and sixth dorsal segments (figs. 18 and 19).

A neurologic examination, March 24, showed loss of the umbilical reflex. The patellar and Achilles tendon reflexes were normal. Plantar irritation caused flexion of the toes on both sides. The tactile sensation was normal in the trunk and lower extremities. The senses of vibration, motion and position were normal. The pain and temperature senses were lost on the left side below the fifth dorsal segment (a trifle higher than on previous examination). On the right, the analgesia and thermanesthesia were slightly lower, having dropped to the seventh dorsal segment (figs. 20 and 21).

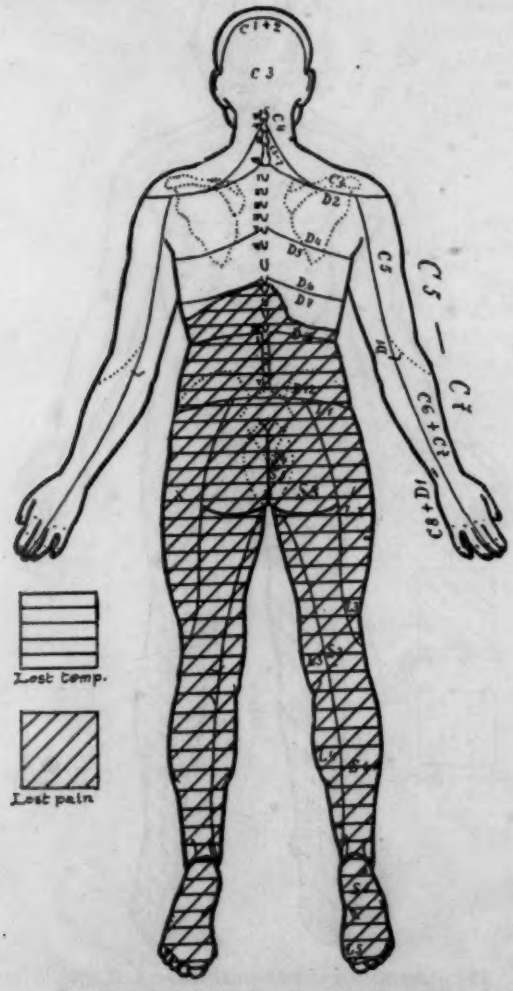

Fig. 21 (case 18).—Back view of patient.

The area of lost pain and temperature sensation extended to a higher level in relation to the anterolateral segment divided than in any previous chordotomy. This we believe is due to the incision being carried deeper in the extreme anterior portion of the tract, the section of the cord fibers extending to the median side of the anterior roots. The division of one motor root is of no consequence in the upper dorsal region.

CASE 19.—C. L., a man, aged 65, suffered excruciating pain in the legs of unknown etiology; a bilateral chordotomy was done.

In January, 1925, he first noticed a "numb" feeling over the entire body, following exposure to cold while digging a well with his feet in ice water. He shortly developed sharp, intermittent pains in the thighs and lower part of the abdomen. Catheterization was necessary the next day, but not since. The inter-

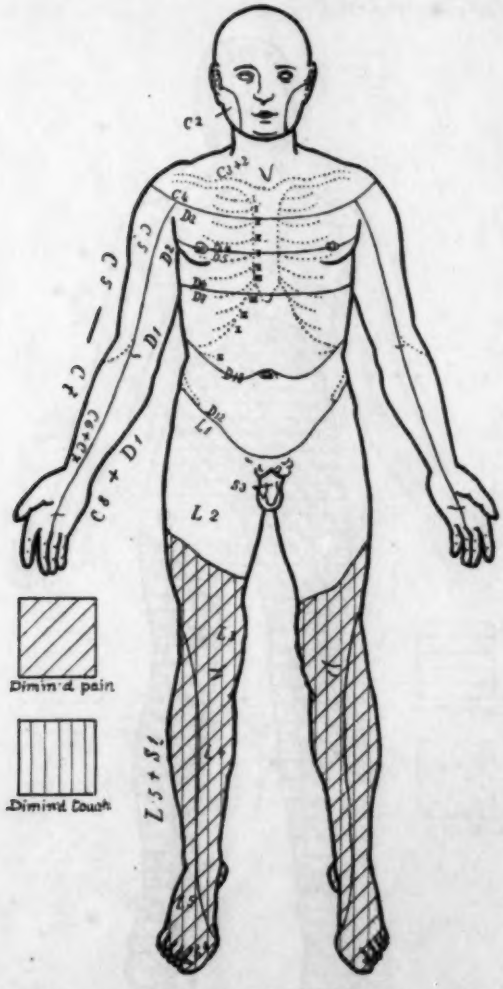

Fig. 22 (case 19).—Areas of diminished pain and tactile perception before operation.

mittent pains, radiating down both legs, but most severe in the left, had persisted. He had some involuntary jerking of the left leg and foot from the onset of the trouble. This had now extended to the right leg and foot. The contractions of the adductor of the left thigh and extensors and flexors of the toes were most marked. These jerking movements were very painful. He had polydipsia and polyuria. The urine examination was negative.

Physical and neurologic examinations, March 20, 1925, were negative except that the plantar reflex was lost in both feet; the tendon of Achilles tenderness was lost, and there was a considerable tremor of both legs when he was standing in the Romberg position. There were coarse, quite rhythmical movements of both lower extremities combined with occasional spasmodic contractions. The patellar reflexes were very active, especially the left. Pin point and light touch

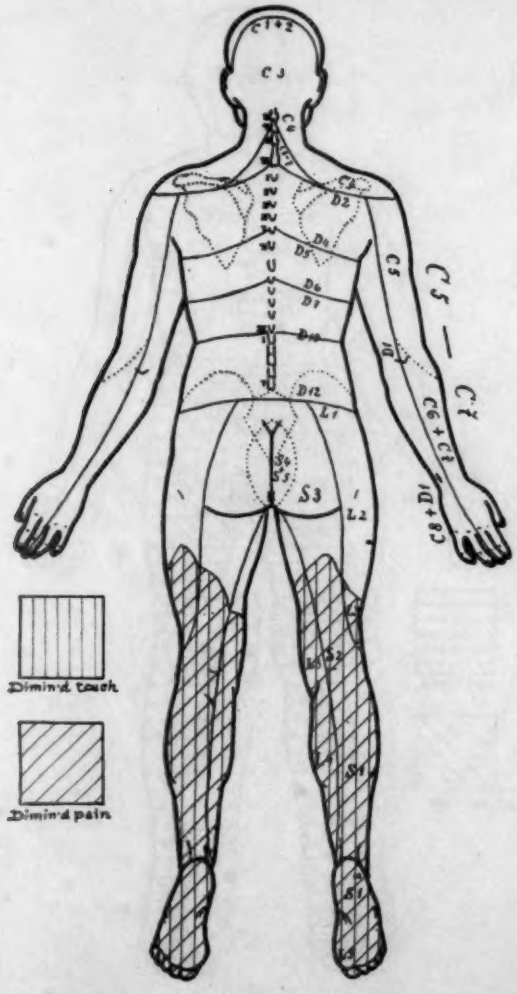

Fig. 23 (case 19).—Back view of patient.

sensations were diminished below the lower third of the thigh in front and the middle of the thigh behind (figs. 22 and 23). The spinal fluid was negative to the Wassermann test; clear, colorless, and gave moderate clouding to phenol. In phase 1 of the Nonne-Apelt reaction there was a faint ring; in phase 2, slight opalescence. The colloidal gold curve was 00122210000; mastic, 222100.

On examination, June 8, the patient complained of severe pain and jerking of the legs and feet, with much pain in the soles of the feet. He had a tingling and

burning sensation in the legs and feet. The Achilles reflex was now lost on both sides. Sensation was the same as before. The vibratory, motion and position senses were normal.

A month later he returned, complaining bitterly of the sharp, shooting pains which now extended downward from the inguinal region on both sides. There also was severe burning along the fibular surfaces and feet. The patellar reflexes

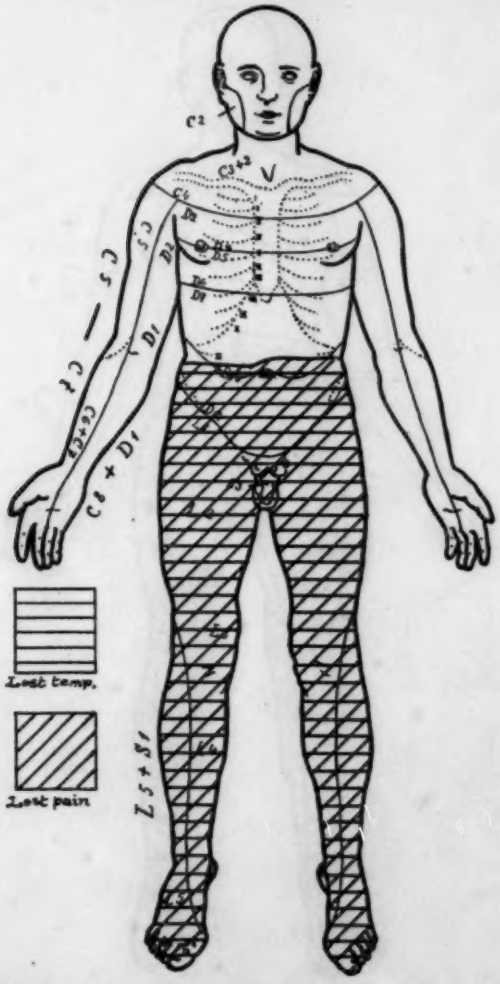

Fig. 24 (case 19).—Areas of lost temperature and pain seventeen days after bilateral chordotomy at eighth dorsal segment; section of each anterolateral tract to a depth of 3 mm. in front of dentate ligament and forward through respective anterior roots.

were normal. The Achilles tendon and plantar reflexes were lost. The light touch sense in the lower extremities had now returned to normal. Pin point pain was still markedly diminished in the same area as before. The tendon of Achilles tenderness was lost. Motion, position and vibratory senses were normal. The thermal sense probably was normal but discrimination was not always accurate.

A definite diagnosis could not be made. Some of the symptoms suggested a tumor or inflammatory condition in the cauda equina. The pain was so severe that exploration even with the very doubtful diagnosis was considered advisable.

July 23, the posterior spinous processes and the laminae of the tenth, eleventh and twelfth dorsal and first and second lumbar vertebrae were removed. No evidence of a pathologic condition could be found. The relief of pain to be

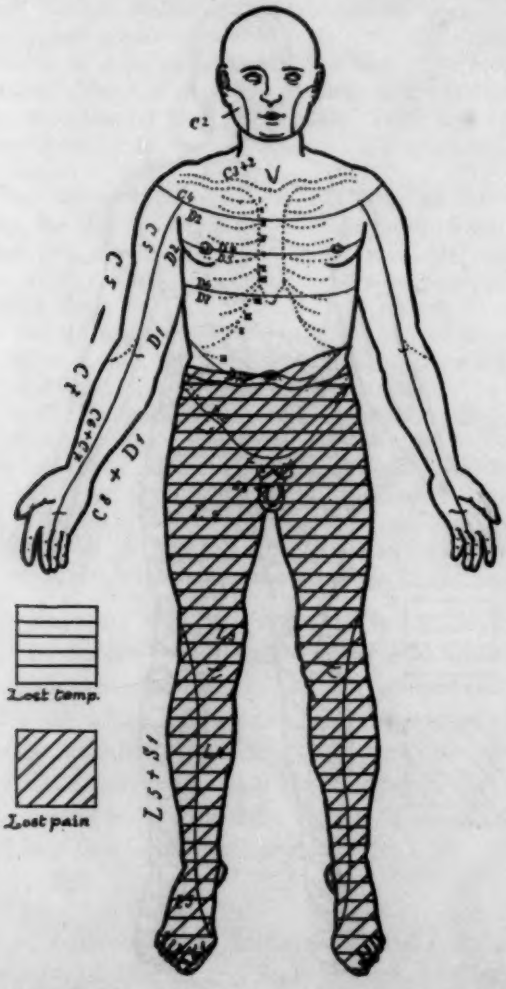

Fig. 25 (case 19).—Areas of lost temperature and pain more than five months after bilateral section of anterolateral tracts at eighth dorsal segment; the level of analgesia and thermanesthesia has remained practically the same.

obtained by a chordotomy at this level was not known, but seemed worth determining. Bilateral division of the anterolateral tracts was made to a depth of 3 mm. at the second lumbar segment. As the motor roots at this level are important, the section of the cord on each side extended only from in front of the dentate ligament to the respective anterior root.

The pain was entirely relieved in the feet, but no change in the pain sensation was noted elsewhere. Accordingly, section of the anterolateral tracts in the usual upper dorsal region was recommended.

August 15, the posterior spinous processes and the laminae of the fourth, fifth and sixth dorsal vertebrae were removed, and a bilateral chordotomy at the level of the fifth dorsal vertebra (eighth dorsal segment) was done. The antero-

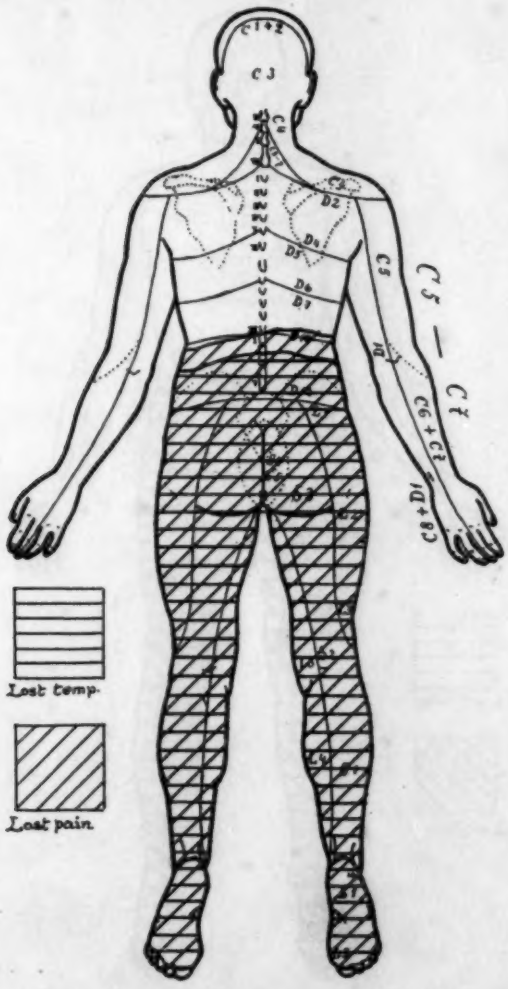

Fig. 26 (case 19).—Back view of patient.

lateral tracts were divided to a depth of 3 mm. just anterior to the dentate ligament. The incisions were then carried forward through the anterior roots on each side.

The severe shooting pains in the legs were completely relieved. The bladder had to be emptied by suprapubic pressure. A neurologic examination by Dr. W. A. Smith, Aug. 1, 1925, showed involuntary twitchings of the feet and legs still present. The patellar reflexes were normal. The tendon of Achilles and

plantar reflexes were lost, and the tendon of Achilles tenderness was lost. The vibratory sense was present in the ankles. The pain sense was lost below the level of the umbilicus on the right and to about 2 inches (5 cm.) above the umbilicus on the left. A neurologic examination by Dr. John L. Garvey, September 7, revealed that the patient complained of no pain in the lower extremities but now had a sensation of needles touching but causing no pain in the legs. He also complained, as before operation, of burning and jerking of the legs. The right patellar reflex was normal, the left diminished, and the Achilles tendon reflex was diminished. The plantar reflex was normal on both sides. The vibratory sense was present. The tendon of Achilles tenderness was lost. The sense of motion and position was normal. The pain sensation was lost to the umbilicus on the right, to just below the umbilicus on the left (fig. 24). There was no motor paralysis but the patient would not try to walk, going about in a wheel chair. Shortly thereafter he was persuaded to walk.

The patient returned to the hospital, Jan. 21, 1926. He had had no return of the former pain in the legs but had had sharp, intermittent pains in the chest, the abdomen, the shoulders and the upper part of the arms. He still had burning in the legs, most severe on the left. On the right, only the posterior aspect from the middle of the thigh down was involved. He had jerking of the feet and toes when recumbent but not when sitting or standing, and had incontinence of urine. He now used crutches because the "knees gave way." On neurologic examination, Jan. 25, 1926, the umbilical reflexes were not obtained. The patellar reflexes were active and equal; the tendon of Achilles reflexes were present, more prompt on the right. Plantar irritation caused extension of the toes on the right, no movement on the left. The tendon of Achilles tenderness was lost on both sides. The vibratory, motion and position senses were normal. The tactile sense was normal. The pain sense was lost to the level of the umbilicus on the right and to an ascending line 2 inches (5 cm.) above the umbilicus on the left. The temperature sense was lost below a horizontal level just beneath the umbilicus (fig. 26).

A positive diagnosis was not made. The patient, however, was greatly relieved by the loss of the excruciating pain which radiated from the inguinal region down both legs. The presence of a burning sensation in an area in which both pain and temperature sensations are completely lost is difficult to explain. A point of interest was the difference in the levels of analgesia and thermanesthesia, the former being a segment higher on the left and a trifle higher on the right. The reverse has been noted in a previous chordotomy case.

RÉSUMÉ

The series of nineteen cases that appear in the American literature embrace the reports of Martin and Spiller, Beer, Frazier, Leighton, and Frazier and Spiller. The operation has also been performed by Elsberg, Ernest Sachs and others in this country but the cases have not been published. The primary conditions in the foregoing series which ultimately made operation for the relief of pain necessary were: primary malignant disease of the spine, three; gunshot injury of the spine, three; tabes dorsalis, three; myelitis, two; carcinoma of the rectum, two; carcinoma of the cecum, one; carcinoma of the uterus, one; carcinoma of the breast, one; sarcoma of the thigh, one; shell wound of the sciatic

nerve in the pelvis, one; pain in the vagina and rectum, unknown origin, one. Most of the malignancies have metastasized to the spine or to the pelvic glands with direct involvement of the lumbosacral plexus.

There was satisfactory relief in fourteen, partial relief in five cases. By satisfactory relief was not necessarily meant complete absence of pain, judging from the records. Actual complete absence of pain was, however, obtained in most of those listed as satisfactory. One patient required three operations before even approximately satisfactory relief was obtained. Unilateral chordotomy was performed in six cases, bilateral in twelve. One of the latter had the two anterolateral columns sectioned at different times.

Little data relative to the area of analgesia which should be expected following section of an anterolateral tract can be obtained from some of the reported cases. This is partially due to the indiscriminate use of the cord segments as synonymous with the vertebrae. For example, the operation is reported as a section at the level of the sixth dorsal segment when as a matter of fact it was the sixth dorsal spinous process or perhaps the fifth dorsal which had been removed, placing the actual division of the cord at the eighth or ninth dorsal segment. We realize that a definite variation does exist between a given vertebra and the numerically corresponding segment. For this reason, we have mentioned in the abstracts of the foregoing cases the number of the spinous process removed during the laminectomy whenever such data was reported.

Section of the anterolateral tracts to control pain was, until recently, little used by European surgeons. The early reports embrace only four cases. Nonne operated in three cases of tabes; one patient received relief; one developed a paraplegia, and one died from the operation. Tietze at Förster's request operated successfully in one case. Recently, Sicard and Robineau [13] reported twelve patients operated on in the previous year. The results were on the whole satisfactory.

Our series of nineteen cases embrace the following primary conditions: carcinoma of the uterus or cervix, nine; carcinoma of the breast, two; sarcoma of the leg, two; carcinoma of the prostate, one; carcinoma of the lung, one; retroperitoneal malignancy, one; pain in the legs associated with spasmodic contractions, one; pain in the legs of unknown origin, one, and avulsion of the lumbosacral plexus (traumatic sciatic neuralgia), one. The cases of carcinoma of the uterus or cervix had extensive pelvic metastases, probably with direct involvement of the lumbosacral plexus. The two cases of carcinoma of the breast, the two of sarcoma of the femur or tibia and the one of carcinoma of the lung had metastases to the vertebrae.

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13. Sicard and Robineau: Cordotomie laterale anterieure pour Algies incurables, Rev. neurol. **1**:21 (Jan.) 1925.

Two patients required a second chordotomy; one had relief for only ten days after the first operation; the other had no relief from the first chordotomy although the area of distribution of the great sciatic nerve was analgesic. Both had complete relief after the second operation. A third patient had three chordotomies, the first two giving analgesia only in the distribution of the sciatic nerves. One, case 19, actually had two chordotomies but was not listed as a failure at the first since the section of the anterolateral tracts was made in a lumbar segment, primarily to determine the resulting analgesia and was only incidental to an exploratory laminectomy.

The final results in our series of nineteen cases were: complete relief of original pain in sixteen; partial relief in two, and complete but apparently temporary relief in one. A bilateral chordotomy was performed on seventeen, a unilateral on two patients. Rhizotomy was combined with unilateral section of the anterolateral tracts in one case and with bilateral section in another.

Numerous interesting observations have been made in these nineteen cases. The level of analgesia must, of course, be below the segment of the cord sectioned, but beyond this self-evident fact the loss of pain sense may bear no relation to the segment incised. Rather it is the depth of the incision, particularly in the anterior portion of the anterolateral tract, which determines how closely the level of analgesia approaches the level of sensory distribution of the segment operated on. Illustrative examples are cases 1, 6, 9, 12 and 17. In case 1 bilateral section at the eighth dorsal segment resulted in loss of pain and temperature below the eleventh dorsal segment on the left side and only diminished pain on the right. The incision was made 2.5 mm. deep on the right while the left tract, which carries the fibers from the right leg, was divided slightly less deeply. In case 6, a bilateral chordotomy between the sixth and the seventh dorsal segments resulted only in loss of pain and temperature sensation in the distribution of the great sciatic nerve. A second chordotomy at a slightly greater depth gave much higher analgesia. Case 12 presents the most striking example: two bilateral chordotomies at a depth of 3 mm., the first at the sixth and the second at the third dorsal segment, resulted only in analgesia of the region of the distribution of the sciatic nerve in the lower part of the legs (figs. 10 and 11). However, a third chordotomy 0.5 mm. deeper, although at a lower level, gave a much higher analgesia and thermanesthesia.

The highest level of lost pain and temperature sensation was obtained when the incision of the cord extended directly forward through the anterior root as in case 18. This resulted in a level of analgesia and thermanesthesia approximating closely the level of sensory distribution of the segment operated on.

The level of lost pain sensibility may or may not correspond to the level of lost temperature sense. As a rule, these two sensations are lost in approximately the same area. Pain perception may, however, be lost at a higher or lower level than temperature (figs. 9 and 15). Isolated areas of preserved pain or temperature sense may occur in regions otherwise completely anesthetic to these sensations. In some patients, we noted a disturbance of pain or temperature sensations, the perceptions being either greatly diminished, frequently but irregularly lost, or usually misinterpreted.

A peculiarity noted in some patients was the interesting observation that the original pain of which the patient complained was lost although the area to which it had been referred was not completely analgesic. We have also noted occasionally that a pin point may be distinguished from a pin head although the sense of pain from the pin prick is absent. The tickle sense may be pronounced on the sole of the foot even when this area is completely analgesic.

The cutaneous and deep reflexes are not changed by section of the anterolateral tracts. When any of these reflexes are modified it means that the incision was carried too far posteriorly or that the operative manipulations have directly injured the crossed pyramidal tracts. Motion of the extremity should not be affected and any loss must be attributed to the same factors that affect the reflexes. Tactile sensation has never been changed in any of our series. Likewise, the senses of motion and position, vibration and localization are preserved.

OPERATION

The operation offers no special difficulties to the neurologic surgeon but it is not advocated for the surgeon who is not experienced in the special technic of intraspinal surgery. The exact level at which chordotomy should be performed varies somewhat with the case. It is essential that the division of the anterolateral tracts shall be at least four segments above the area to be rendered analgesic. This is to assure crossing of all the afferent fibers. In cases of upper abdominal pain we have added to the chordotomy division of the posterior nerve roots in the exposed field. This adds about one segment to the area of analgesia and protects against the possibility of some fibers crossing at a higher level than was anticipated. As a general rule, we have made the anterolateral tract division at the level of the fourth, fifth or sixth dorsal vertebrae. The cord at this level is more easily accessible than at other levels and analgesia should be obtained below the eighth to the tenth dorsal segment. Usually three posterior spinous processes are removed together with the laminae, as adequate exposure is essential. Occasionally only two laminae need be removed, the exact number depending on the depth of the wound. The dura is incised practically the entire length of the bony opening. The arachnoid is then carefully

and freely opened so that the operative procedure can be done from within the arachnoid. This is essential as the presence of the arachnoid anterior to the dentate ligament, should it lie against the cord, makes exact attachment of the dentate ligament and of the emergence of the anterior root obscure. A dentate ligament attachment is then divided, the dentate ligament grasped with fine forceps and the cord carefully rotated, exposing its anterolateral aspect.

Two methods may be used in dividing the cord: Either the Frazier chordotomy needle or hook may be inserted and then incision made against the hook, using this special instrument as a guide to the needed depth, or a very fine pointed, sharp knife can be inserted directly. The knife should be marked so that a depth of 3 mm. can be definitely determined. In our earlier operations, we followed Frazier's technic and divided to a depth of only 2.5 mm. We have found that 3 mm. gives more satisfactory results. Incision is made just anterior to the dentate ligament reflection from the cord, carried almost directly medially, but slightly forward, to a depth of 3 mm., and brought out through the origin of a motor root. I think it essential that at the level of the emergence of an anterior root the incision should be at a depth of from 2 to 2.5 mm.; i. e., the point of the knife, starting at a depth of 3 mm. in front of the dentate ligament should be carried directly forward parallel to the anteroposterior axis of the cord so that the point of the knife will appear at the median side of the anterior root, the particular fibers coming off at this level being divided. Little, if any, bleeding results from the cord incision. When bilateral chordotomy is indicated, the dentate ligament on the opposite side is grasped after division of its attachment to the dura, the cord rotated and a similar procedure carried out. The dura is then closed with a continuous silk suture and the muscle planes with interrupted sutures.

Throughout the operation no pressure should be brought on the cord. All sponging should be with cotton pledgets and no traction made on either anterior or posterior roots beyond that necessary to assure proper rotation of the cord. The use of suction apparatus almost entirely eliminates the necessity of sponging and materially facilitates the performance of the more delicate parts of the operation. We have found it advisable in certain selected cases to divide the three posterior nerve roots exposed in the field. If a unilateral chordotomy is being performed, the posterior nerve roots of the opposite side would be the ones divided. The two technical points, however, which we wish to emphasize especially are the complete freeing of the cord from the arachnoid and the division of the anterior median portion of the anterolateral column.

The postoperative treatment has not differed from that following laminectomy. If difficulty in urination is encountered, I have thought it advisable to empty the bladder by pressure above the pubis rather

than by catheterization. With the short laminectomy necessitated by this operation, the patients can be turned from side to side without difficulty. Frequently the patients complain of some pain on moving the arms when the incision has been made over the third, fourth and fifth dorsal vertebrae. This pain is referred directly to the operative wound and generally disappears within a few days.

Following unilateral division of the anterolateral tracts properly performed, there should be complete loss of pain and temperature sense on the opposite side up to a level of from three to five segments below the level of section. At times, the area of analgesia is still higher. Particularly is this true if the incision extends, as I now believe it should, through the anterior root as in case 18, in which the level of analgesia and thermanesthesia is practically the same as the level of cord section. On the other hand, the area may be much lower, probably because certain fibers had not yet crossed, or the incision had not been carried to a sufficient depth.

CONCLUSIONS

Section of the anterolateral tracts is a justifiable operation to relieve intractable pain. In cases of malignant disease it is comparable to the more common palliative operations such as gastro-enterostomy in carcinoma of the stomach.

Rhizotomy alone has not given satisfactory relief of pain. It may be combined with chordotomy to insure a high level of analgesia.

Section of an anterolateral tract should give analgesia and thermanesthesia on the opposite side up to a level approximately from three to five segments below the tactile distribution of the segment incised. Extending the section through the base of an anterior root may give loss of pain and temperature sense to a level corresponding closely with the segment operated on.

The motor function should not be impaired. Tactile, vibratory, localization, deep pressure and motion and position perceptions are preserved. Cutaneous and tendon reflexes are unchanged.

The chordotomy should extend to a depth of 3 mm. immediately in front of the dentate ligament and pass directly forward through the exit of fibers of an anterior root. This carries the incision to the anterior horn and just to the median side of a motor root. Bilateral section of the anterolateral columns should be performed when pain is confined to one side if the nature of the lesion is such that bilateral pain will probably soon appear.

In a series of nineteen cases of my own and nineteen cases in the literature, reviewed here, the majority of the results were satisfactory.

Chordotomy with section of the anterolateral columns is the preferable means at our disposal to relieve intractable pain in the lower half of the body.

WOUNDS OF THE HEART

THE TECHNIC OF SUTURE *

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I. INTRODUCTION

The successful suture of a wound of the heart is not an uncommon surgical feat. To the individual surgeon, however, the experience of performing the operation is rare, and the subject may therefore receive but little consideration until the occasion for carrying out the operation is presented. In the numerous case reports of suture of wounds of the heart little attention has been directed toward the method of placing the sutures for the closure of the wound. "The surgeon having this job in hand will take it all in the day's work, and just as he plunges his hand into the abdomen into a mass of blood in a case of ruptured spleen or in a case of ruptured tubal gestation and seizes the bleeding spot, so he will now plunge his hand into the pericardium and seize the heart, and, by digital compression, control the hemorrhage, and proceed to suture the wound." [1]

The purpose of this article is to review certain phases of the subject and to present a method that may aid in the suture of wounds of the heart.

II. HISTORY

The history of wounds of the heart may be divided into the following periods:

1. The period of mysticism in which wounds of the heart were considered necessarily fatal. It extended into the seventeenth century.
2. The period of observation and experiment.
3. The period of suture, beginning in 1882.

1. PERIOD OF MYSTICISM

The Heart is the chiefe mansion of the Soule, the organe of the vitall faculty, the beginning of life, the fountaine of the vitall spirits, and so consequently the continuall nourisher of the vitall heate, the first living and last dying, which because it must have a naturall motion of itself, was made of dense solide and more compact substance than any other part of the body.[2]

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* From the Laboratory of Experimental Surgery, the Western Reserve School of Medicine and the Lakeside Hospital.

1. Ballance, C. A.: The Bradshaw Lecture on the Surgery of the Heart, delivered before the Royal College of Surgeons, Dec. 11, 1919, London, Macmillan Company, 1920.

2. Paré, Ambrose: The Workes of That Famous Chirurgion Ambrose Parey, translated by T. Johnson, London, T. Cotes, 1634.

The story opens with the legends of Homer [3] about the ninth century B. C. In the Iliad is recorded the observation of the movements of the heart transmitted through a spear that had transfixed the heart of Alkathoos. "The hero Idomeneus smote him in the midst of the breast with the spear. . . . And he fell with a crash, and the lance fixed in his heart, that, still beating, shook the butt end of the spear." Again, Homer,[4] in his narration of the death of Sarpedon, sang:

> Not so Patroclus' never erring dart;
> Aim'd at his breast, it pierced the mortal part,
> Where the strong fibers bind the solid heart.
> Th' insulting victor with disdain bestrode
> The prostrate prince, and on his bosom trod;
> Then drew the weapon from his panting heart,[5]
> The reeking fibers clinging to the dart;
> From the wide wound gush'd out a stream of blood,
> And the soul issued in the purple flood.

Hippocrates [6] stated that "a severe wound of the bladder, of the brain, of the heart, of the diaphragm, of the small intestine, of the stomach and of the liver is deadly," but he did not emphasize any special danger of wounds of the heart as did later writers. Wounds of the heart undoubtedly occurred in the great Persian wars and in the subsequent struggles for supremacy in Greece. Aristotle, Ovid, Celsus, Pliny and Galen regarded them as *absolutely and necessarily fatal.*

Aristotle [7] said:

> The heart alone of all the viscera cannot withstand serious injury. This is to be expected because when the main source of strength (the heart) is destroyed there is no aid that can be brought to the other organs which depend upon it.

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3. Homer: The Iliad, xiii, line 442, translated by Lang, Leaf and Myers, New York, Macmillan Company, 1922, p. 259.

4. Homer: The Iliad, xvi, lines 588-625, translated by Alexander Pope, London, George Bell & Sons, 1904, p. 299.

5. In 1898 Empress Elizabeth of Austria perished suddenly on the withdrawal of a file from the heart. Death was due to compression of the heart by the collection of blood in the pericardial cavity. Had the signs of increased intrapericardial pressure been heeded, the wound undoubtedly could have been sutured. The procedure could have been carried out most safely if the heart had been exposed at operation before the file was withdrawn. But at this late date, recent as it may seem, the pulsating heart of the human being had been exposed to view only a few times and the veil of mystery (to the surgeon) was just being lifted.

6. Hippocrates: The Genuine Works of Hippocrates, Section 6, Aphorism 18, translated by Francis Adams, New York, William Wood & Co., **2**:252.

7. Aristotle (384-322 B. C.): De partibus Animalium, Lib. III, cap. 4, Opera edidit Academia Regia Borussica **3**:328.

Ovid [8] wrote:

Although Aesculapius himself applies the sacred herbs by no means can he cure a wound of the heart.

Celsus [9] stated:

When the heart is wounded much blood is lost, the pulse weakens, pallor becomes extreme, a cold and foul sweat arises from the stricken body, the extremities become cold and speedy death follows.

Pliny [10] said:

This is the only one among the viscera that is not affected by maladies, nor is it subject to the ordinary penalties of human life; but when injured, it produces instant death.

Wounds of the heart were observed in gladiators, and they were considered uniformly fatal, according to Galen: [11]

Inflammato autem manifeste corde; gladiatores vidimus haud aliter, quam qui cardiaca syncope pereunt, obiise. Igitur si ad ventrem cordis vulnus aliquando peneraverit, protinus magno cum sanguinis fluore moriuntur, idque praecipue, si sinistrae partis venter fuerit vulneratus; si vero non ad ventrem usque pertingat, sed in cordis substantia consistat vulnus, ex ita affectis aliqui non solum ea die, qua vulnerati fuerunt, sed sequenti quoque nocte vivere potuerunt, inflammationis ratione nimirum extincti; atque ii omnes quamdiu vixerint, mentis compotes sunt; unde evidens quoque sibi testimonium sumere potest antiqua secta, quae negat rationalem animae facultatem in corde consistere.

In the opinion of Paulus Aegineta,[12]

When the heart is wounded, the weapon appears at the left breast and feels not as if in a cavity but as fixed in another body, and sometimes there is a throbbing motion; there is a discharge of black blood if it can find vent, with coldness, sweats, and deliquium animi, and death follows in a short time.

Fallopius [13] asserted:

Wounds of the heart are always followed by sudden death. When wounded it cannot heal, being too firm, always in motion, and of an inflammatory heat.

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8. Ovid (43 B. C.-17 A. D.): Epistolae ex Ponto, Lib. I, Epist. III, lines 21-22.

9. Celsus (1st century A. D.): Medicinae Libri Octo, Lib. V, cap. 26, L. Targae, Lugduni Batavorum, by S. and J. Luchtmans, 1791, p. 307.

10. Pliny, the Elder (23-79): Historia Naturalis, Lib. XI, cap. 37, translated by Bostock and Riley, London, H. G. Bohn, **3**:65, 1855.

11. Galen (130-200?): Medicorum Graecorum Opera, volumen VIII, Lipsiae prostat in officina Libraria car. cuoblochii 1824, De locis affectis, edited by D. C. Kühn, T. VIII, Lib. v, cap. 2, p. 304.

12. Paulus Aegineta (625-690): The seven books of Lib. VI, sect. 88, translated by Francis Adams, London, Sydenham Society, 1846, **2**:421.

13. Fallopius (1523-1562): Opera omnia tractatus de vulneribus in genere, cap. 10, Frankfurt, 1600, p. 163.

Wounds of the right ventricle may be differentiated from wounds of the left ventricle; from the former comes dark blood, from the latter, red blood.

Paré [14] wrote:

By these signs you may know that the heart is wounded: If a great quantity of blood gush out, if a trembling possess all the members of the body; if the pulse be little and faint, if the colour become pale, if a cold sweate and frequent sowning assayle him, and the extreme parts become cold, then death's at hand. Yet when I was at Turin I saw a certaine Gentleman who fighting a Duell with another, received a wound under his left breast which pierced into the substance of his heart, yet for all that he strucke some blowes afterwards, and followed his flying Enemie, some two hundred paces until he fell downe dead upon the ground; having opened his body, I found a wound in the substance of the heart, so large as would containe one's finger; there was onely much blood poured forth upon the midriffe.

According to Fabricius: [15]

If the heart is wounded the affair is desperate, so also if the pericardium is wounded. It is, therefore, unnecessary to attempt any treatment.

Zacchias (1584-1659), according to Fischer,[16] reported a case of needle wound of the heart in which death did not occur until the sixth day after the injury, "hoc quidem mirabile auditu est" because "the noblest organ of the body cannot survive a solution of its continuity and this is the general medical opinion."

Boerhaave [17] said:

All wounds of the heart deep enough to penetrate into either of its ventricles are mortal.

2. PERIOD OF OBSERVATION AND EXPERIMENT

The idea that all wounds of the heart were necessarily fatal, established by the ancient authority of Aristotle and Galen, remained unchallenged until the seventeenth century when there began a period of independent observation and experiment. It was the period in which Riolan and Harvey made their contributions and, a century later, Morgagni and Larrey.

According to Fischer,[16] who carefully reviewed the early literature of the subject, the first to advance the idea that wounds of the heart

14. Paré (1509-1590): The Workes of That Famous Chirurgion Ambrose Parey, translated from the Latin by T. Johnson, London, T. Cotes, 1634.

15. Fabricius ab Aquapendente (1537-1619): Opera chirurgica, Cap. 21, Patavii, 1666, p. 104.

16. Fischer, Georg: Die Wunden des Herzens und des Herzbeutels, Arch. f. klin. Chir. **9**:571, 1868.

17. Boerhaave (1668-1738): De Vulnere in Genere, Aphorismi de Cognoscendis et Curandis Morbis, Aphorism 170, p. 43.

can heal and that such wounds are not necessarily fatal was Hollerius [18] (1498-1562), and the first authentic description of a healed wound of the heart was by Idonis Wolf [19] in 1642. It took over a century, however, for this new conception to receive recognition.

Sénac,[20] in 1749, stated that wounds of the heart are always serious; nevertheless, a nonpenetrating wound may heal and may not be fatal. An important advance in the knowledge of the subject was made by Morgagni [21] in 1761 by pointing out the danger of compression of the heart due to hemorrhage into the pericardium. Larrey,[22] who had had considerable experience in the treatment of wounds of the pericardium and heart and who had performed some experiments on the heart in dogs, stated that the view generally held by physicians concerning these wounds was too grave. In 1829 he reported a case that he treated by passing a catheter into a stab wound of the chest; he obtained three beakers of wine colored fluid, and after the passage of a sound obtained four more beakers of similar fluid. This, according to Larrey, was the first case of a wound of the pericardium in which the patient recovered.

The treatment of wounds of the heart during the first half of the nineteenth century consisted of absolute quiet, the application of leeches, venesection, and the passage of a catheter or a sound into the wound for the evacuation of fluid from the pericardial cavity. Dupuytren [23] advised venesection to be carried out almost to the point of exsanguination. Jobert [24] in 1839 stated:

> The duration of life is in proportion to the quantity of blood lost and especially to that which is contained in the pericardium. I have seen death occur promptly in one of these patients, not because of the extent of the wound, but because the blood which had been shed, not being able to escape through the narrow opening in the pericardium, compresses the heart and opposes the accomplishment of its function. This effect is produced only by a compression taking place suddenly and it does not take place in the same manner when the compression is established

18. Hollerius, J.: Communis aphorismi allegati, quoted from Fischer (Footnote 16).

19. Wolf, Idonis, cited by Fischer (Footnote 16).

20. Senac, J. B.: Traité de la Structure du Coeur, de son Action, et de ses Maladies, Paris, Briasson, 1749, **2**:366.

21. Morgagni, J. B.: De Sedibus et Causis Morborum, Lipsiae sumptibus Leopoldi Vossii, 1829.

22. Larrey, D. J.: Clin. Chir., Paris, **2**:284, 1829.

23. Dupuytren, Guillaume: Clinical Lecture on Surgery, delivered during sessions of 1834 at the Hotel Dieu, Paris, Leçons Orales de Clinique Chirurgicale on Wounds of the Heart: Their Varieties, Causes, Symptoms, and Treatment, Lancet **1**:767, 1834-1835.

24. Jobert, J. A.: Réflexions sur les plaies pénétrantes du coeur, Arch. gén. de méd. **6**:1, 1839.

little by little, as in hydropericardium, for example. If the blood continues to be poured out of the cavities of the heart in great abundance, death will occur promptly, but here again the feebleness of the patient and syncope sometimes stop the beating of the heart, and there is formed a clot which opposes the further escape of blood.

Numerous case reports appeared during the remainder of this period. Cases were compiled, the clinical signs and symptoms were analyzed, and the pathology was studied. Purple [25] in 1850 compiled forty-two cases, eleven of which were from American sources. In 1868 appeared a comprehensive monograph by Georg Fischer [16] with a compilation of 452 cases, only 10 per cent of which resulted in recovery. That wounds of the heart might be treated by suture was suggested, but not carried out, by Roberts [26] in 1881.

3. PERIOD OF SUTURE

The first experiments to suture wounds of the heart were performed by Block [27] on rabbits in 1882. Wounds made experimentally were sutured, with recovery of the animal, and the feasibility of applying the procedure to the human heart was suggested. The subject, however, was met with opposition. Thus, Billroth [28] in 1883 stated that "the surgeon who should attempt to suture a wound of the heart would lose the respect of his colleagues"; Riedinger [29] in 1888 wrote, "the suggestion to suture a wound of the heart, although made in all seriousness, scarcely deserves notice"; and Stephen Paget [30] in 1896 stated that "surgery of the heart has probably reached the limits set by Nature to all surgery: no new method and no new discovery can overcome the natural difficulties that attend a wound of the heart. It is true that 'heart suture' has been vaguely proposed as a possible procedure, and has been done on animals, but I cannot find that it has ever been attempted in practice." Little support was given to the procedure until 1895 when Del Vecchio [31] demonstrated to the Eleventh International

25. Purple, S. S.: Statistical Observations on Wounds of the Heart, and on Their Relations to Forensic Medicine, with a table of forty-two recorded cases, New York J. M. & Collateral Sc. **14**:411, 1855.

26. Roberts, J. B.: The Surgery of the Pericardium, Ann. Anat. & Surg. **4**: 247, 1881.

27. Block: Verhandlungen der Deutschen Gesellschaft für Chirurgie, Elften Congress, Berlin, 1882, Part 1, p. 108.

28. Billroth, Theodore, quoted from Jeger, Ernst: Die Chirurgie der Blutgefässe und des Herzens, Berlin, A. Hirschwald, 1913, p. 295.

29. Riedinger: Verletzungen und Chirurgische Krankheiten des Thorax und seines Inhaltes, Stuttgart, Ferdinand Enke, 1888, Part 42, p. 189.

30. Paget, Stephen: The Surgery of the Chest, London, John Wright & Co., 1896, p. 121.

31. Del Vecchio, S.: Sutura del Cuore, Riforma med. **11**:38, 1895

Medical Congress at Rome healed wounds of the heart in dogs following suture. Almost within a year from this date three attempts to suture wounds of the human heart were made. The first was by Cappelen [32] of Christiania, Sept. 4, 1895; the second [33] was by Farina [34] of Rome, March, 1896, and the third was by Rehn [35] of Frankfurt, Sept. 9, 1896.

CAPPELEN'S CASE

A man, aged 24, received a stab wound in the fourth left interspace in the midaxillary line. He walked home bleeding from the wound. About one hour later he was admitted to the hospital, at which time he showed signs of hemorrhage, an imperceptible pulse and distant, faint heart sounds. Bleeding from the wound had ceased. Camphor stimulated the heart so that the pulse could be felt and consciousness returned. There was dulness to percussion over the left side of the chest.

At operation chloroform anesthesia was used. The third and fourth ribs on the left side were resected. The intercostal artery was not cut. The left pleural cavity contained 1,400 cc. of blood. The lung was not injured. Bleeding continued from the depth of the operative field and an opening in the pericardium large enough to admit the tip of the finger was found. The pericardium was distended with blood. It was opened. A wound in the left ventricle 2 cm. long was sutured with chromic catgut and a bleeding coronary artery was ligated. The rhythm of the heart was regular throughout the operation.

During the postoperative period, which lasted two and one-half days, the pulse was rapid; cyanosis was present, and there was a slight fever. The cause of death was anemia and pericarditis. The wound had not penetrated into the cavity of the left ventricle. The bleeding had occurred from the coronary artery.

FARINA'S CASE

The first case of surgical interference on the heart which I had the opportunity of performing was carried out in March, 1896, at the Spedala della Consolazione. The patient was a man 30 years of age who received a blow from a very fine and sharp dagger in the fifth intercostal space in the parasternal line. The wound penetrated to the cavity in an oblique direction from above downwards and from without inwards. It wounded the pericardium and penetrated into the ventricle. The wound in the myocardium was about 7 mm. long. I removed the fifth costal cartilage and a bit of the rib for about 15 cm. Then I strongly retracted the fourth and sixth costal cartilages. I arrived on the wounded heart. I sutured the wound with three silk sutures, and between these particular points I placed two others of less importance. Everything went well till the fifth day, when a violent bronchopneumonia declared itself on the right side and in three days killed the patient. The thoracic wound healed by primary intention.

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32. Cappelen, A.: Vulnia Cordis, Sutur af Hjertet, Norsk. Mag. f. Lægevidensk. **11**:285, 1896.

33. Most writers have given to Farina the credit for first suturing a wound of the human heart.

34. Farina: Discussion, Centralbl. f. Chir. **23**:1224, 1896.

35. Rehn, L.: Ueber Penetrierende Herzwunden und Herznaht, Arch. f. klin. Chir. **55**:315, 1897.

At the necropsy the wound in the heart was found perfectly healed. The heart was not allowed to be preserved for further study. It was precisely because of my irritation at this fact that I have not published any communication on this interesting case. (From a personal letter by Farina to John Bland Sutton, May, 1910.)

REHN'S CASE

A man, aged 22, was stabbed with a knife in the fourth interspace, three fingerbreadths to the left of the sternal margin. After a period of unconsciousness, which lasted three hours, the patient revived sufficiently to take about 300 paces, when he fell to the ground. He was later found almost lifeless and was taken to a hospital. The first day following the injury the sensorium cleared, the pulse became stronger and dyspnea decreased. During the second day, signs of extreme circulatory failure with cyanosis and marked dyspnea developed and the operation was performed.

An incision 14 cm. long was made in the fourth left interspace and the fifth rib was divided in the mammary line. The pleura was opened. Blood distended the pericardium and oozed from the stab wound which entered it. The pericardium was opened widely and the blood within it was removed. A wound 1.5 cm. long was found in the right ventricle from which there was active bleeding. This was controlled by placing a finger over the wound, but difficulty was experienced in keeping the finger properly placed. There was less bleeding during diastole than during systole. The wound was closed with three silk sutures placed during several diastolic phases. The pulse immediately improved. After the blood was removed from the pleural and the pericardial cavities an iodoform gauze drain was placed in each.

The patient recovered and was able to return to work.

Experiments by Bode [37] and Salomoni [38] further demonstrated the healing of such wounds following suture; and Elsberg,[39] by resecting a third of the heart in dogs and in rabbits, with subsequent recovery, showed that the heart could tolerate extensive surgical procedures.

There has appeared in the literature a large number of cases in which wounds of the heart have been sutured. Ten years after he had performed the first successful suture, Rehn [40] compiled 124 cases, in 40 per cent of which the patients had recovered, and in 1920 Tuffier [41] assembled 305 cases, in 50.4 per cent of which the patients had recovered. A surgical procedure was thereby introduced which has decreased the mortality of wounds of the heart about 40 per cent.

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37. Bode, F.: Versuche über Herzverletzungen, Beitr. z. klin. Chir. **19**:167, 1897.

38. Salomoni: Beitrag zur Chirurgie des Herzens, abst. in Centralbl. f. Chir. **23**:1224, 1896.

39. Elsberg, C. A.: J. Exper. Med. **4**:479, 1899.

40. Rehn, L.: Zur Chirurgie des Herzens und des Herzbeutels, Arch. f. klin. Chir. **83**:723, 1907.

41. Tuffier, T.: La Chirurgie du Coeur, Cinquieme Congres de la Societé Internationale de Chirurgie, Paris, July 19-23, 1920, Extrait. Brussels, Hayez, 1920.

III. HEART TAMPONADE

Compression of the heart by the collection of blood in the pericardial cavity is the cardinal sign in the diagnosis of wounds of the heart. The physiology of heart tamponade has received little attention in our medical schools and the subject merits discussion.

That the heart may be compressed by the collection of blood in the pericardial cavity and the circulation thereby embarrassed was mentioned first by Morgagni [21] in 1761 and later by Jobert [24] and by Franck.[42] In 1884 Rose [43] coined the term "herz tamponade" and presented cases of wounds of the heart that were fatal, not from exsanguination nor from the extent of the injury itself but primarily from compression of the heart by a relatively small amount of blood locked in the pericardial cavity. Experiments by Cohnheim [44] showed that an increased pressure in the pericardial cavity was accompanied by a fall in the arterial pressure and a rise in the venous pressure, and that these phenomena were brought about by the obstruction to the filling of the heart produced by the increased intrapericardial pressure. When this reached the level of the venous pressure, the heart, as shown by Kuno,[45] ceased to function.

In experiments performed by me, an increase in the intrapericardial pressure of a column of water 10 cm. in height was followed immediately by a fall in the arterial pressure and a rise in the venous pressure, and when the intrapericardial pressure was continued the result was fatal. On release of the intrapericardial pressure the arterial and venous pressures returned to the normal levels (fig. 1), the former sometimes showing a compensatory rise [46] of from 10 to 20 mm. of mercury above the normal level. During the tamponade the pulse pressure decreased, the heart rate increased, and the dog became cyanosed. Roentgenograms showed little or no increase in the cardiopericardial shadow during the tamponade (fig. 2). This was to be expected, however, because the sudden increasing of the intrapericardial pressure by a column of water 10 cm. in height added only from 40 to

42. Franck, Francois: Sur le Mode de Production des Troubles Circulatoires dans les Epanchements Abondants du Pericarde, Compt. rend. Soc. de biol. **1**:1242, 1877.

43. Rose, E.: Herztamponade (Ein Beitrag zur Herzchirurgie), Deutsche Ztschr. f. Chir. **20**:329, 1884.

44. Cohnheim, J.: Lectures on General Pathology, London, New Sydenham Society, **1**:21, 1889.

45. Kuno, Yas: The Mechanical Effect of Fluid in the Pericardium on the Function of the Heart, J. Physiol. **51**:221 (Sept.) 1917.

46. In experiments on dogs the compensatory rise above the normal pressure did not occur regularly after release of the increased intrapericardial pressure; it occurred also after section of the vagi, after removal of the stellate ganglions, and after denervation of the heart.

50 cc. to the pericardial fluid and, further, the heart under an increased pericardial pressure contained less blood and was actually smaller than under the normal condition.[47]

The rapidity with which the intrapericardial pressure formed was an important factor in determining the degree of tamponade. In experiments on dogs the injection of 150 cc. of fluid into the pericardial

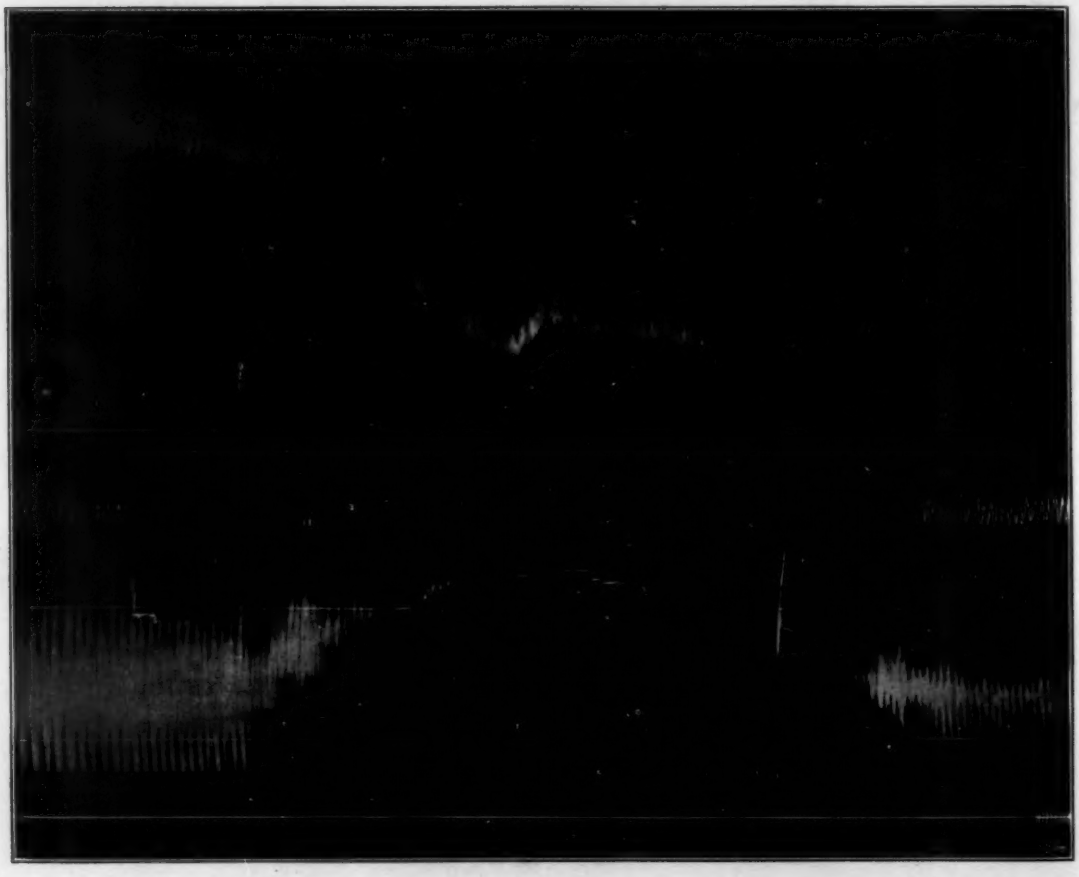

Fig. 1.—Effect of heart tamponade: upper curve shows arterial pressure, femoral; middle curve, venous pressure, innominate, and lower curve, intrapericardial pressure. The intrapericardial pressure was increased 10 cm. of water and caused a marked fall in the arterial pressure and a rise in the venous pressure; on release of the intrapericardial pressure the arterial and venous pressures returned to their former levels. The time is shown in seconds.

47. That the size of the heart decreased under increased pericardial pressure was observed in dogs that died from tamponade due to hemopericardium in experiments in which radium was used to produce mitral stenosis or metallic bands to produce aortic or pulmonic stenosis.

cavity over a period of thirty minutes was fatal. In stab wounds of the human heart in which the opening in the pericardium did not allow the escape of blood through it, 250 cc. produced a fatal tamponade. In cases of effusion in which the fluid formed gradually, from 2 to 4 liters were found in the pericardial cavity, as was reported in cases of scurvy in Russia.[48] In these cases the pericardium dilated and as its limit of elasticity was approached the intrapericardial pressure rose and when it equaled the pressure in the venae cavae, blood no longer entered the heart and the condition became fatal.

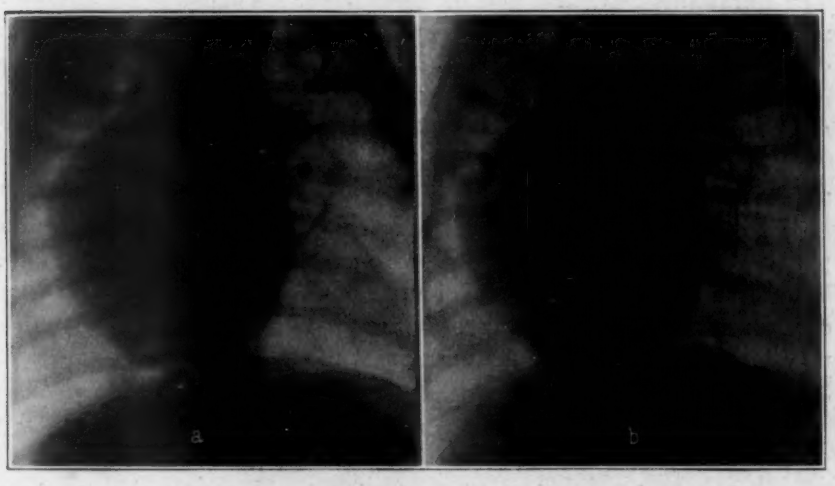

Fig. 2.—Heart of dog, weighing 12 Kg.; a cannula was tied into the pericardium and physiologic sodium chlorid solution was introduced; the roentgen-ray target and the film were at fixed distances from the heart; the position of the dog remained unchanged so that the cardiopericardial shadows permit accurate comparison; *a*, before increasing the intrapericardial pressure; *b*, after increasing the intrapericardial pressure by a column of physiologic sodium chlorid solution 10 cm. in height (sufficient to produce a fatal tamponade). The increase in the size of the cardiopericardial shadow is slight.

IV. OPERATIVE PROCEDURES

1. EXPOSURE OF THE HEART

Numerous methods for the exposure of the heart have been described in which incisions made in the midline parallel to the sternum were utilized, incisions made in various directions to the left or to the right of the sternum, and osteoplastic flaps in which one or more ribs were reflected. Of the various methods that have been proposed the most satisfactory are the median sternotomy and the left intercostochondral

48. Karanaeff, quoted from Kyber: Paracentesis des Herzbeutels, Ztschr. Ruslands, Saint Pétérsbourg, **21**:161, 1847.

thoracotomy. The former provides the best exposure of the heart; the latter provides exposure of both the heart and the left lung.

Median Sternotomy.[49]—The skin incision extends from the level of the second interspace to the midpoint between the umbilicus and the xiphoid. The xiphoid may be either removed or separated on one side from its ligaments and aponeuroses. The underlying structures are freed from the sternum, and a spatula is inserted beneath it to protect the heart. The sternum is split longitudinally with a saw or bone shear to the level of the second or third intercostal space, where it is cut across, care being taken to avoid the internal mammary vessels. The sternum is retracted, and the pleurae are dissected laterally with a moist sponge. The peritoneum is opened and the anterior portion of the diaphragm is incised. The pericardium is opened widely, the incision extending to its reflection on the diaphragm. An excellent exposure of the heart is obtained (fig. 3).

The structures are closed in layers. The sternum should be closely approximated with several silver wire sutures that encircle it.

The operation is not difficult to perform. It is well tolerated by the patient. It is the operation of choice in those cases of wounds of the heart that are not accompanied by a wound of the left lung, making exposure of the latter necessary. If the right lung is involved, exposure may be obtained through the midsternal incision by opening the right border of the mediastinum.

Intercostochondral Thoracotomy.[50]—The incision is made in the left fourth intercostal space extending from the anterior axillary line to the sternum, where it is continued in each direction along the margin of the sternum to expose the third, fourth, fifth and sixth costal cartilages. These costal cartilages are sectioned; the internal mammary vessels are ligated, and the incision is extended through the underlying muscles into the pleura. The structures are retracted and the pericardium is opened. The left lung, the left ventricle, and part of the right ventricle are exposed (fig. 4).

Part of the right ventricle and the base of the heart, including the auricles, are not exposed. The transverse sinus and the venae cavae are inaccessible. The control of hemorrhage by compression of these struc-

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49. Milton, H.: Mediastinal Surgery, Lancet **1**:872, 1897. Rehn (Footnote 40). Duval, P., and Barasty, P.: De la Péricardotomie Thoracoabdominale médiane (Chirurgie du coeur et des gros vaisseaux de la Base), Presse méd. **26**:437 (Aug. 29) 1918. Cutler, E. C.; Levine, S. A., and Beck, C. S.: The Surgical Treatment of Mitral Stenosis: Experimental and Clinical Studies, Arch. Surg. **9**:689 (Nov.) 1924.

50. Spangaro, S.: Sulla tecnica da seguire negli interventi chirurgici per ferite del cuore e su di un nuovo processo di toracotomia, Clin. chir. **14**:227, 1906.

tures, therefore, cannot be carried out when this exposure is used. The exposure is sufficient, however, to permit direct compression of the ventricles in the grasp of the operator.

To increase the exposure of the heart it has been suggested that the second costal cartilage be divided and that the sternum be split

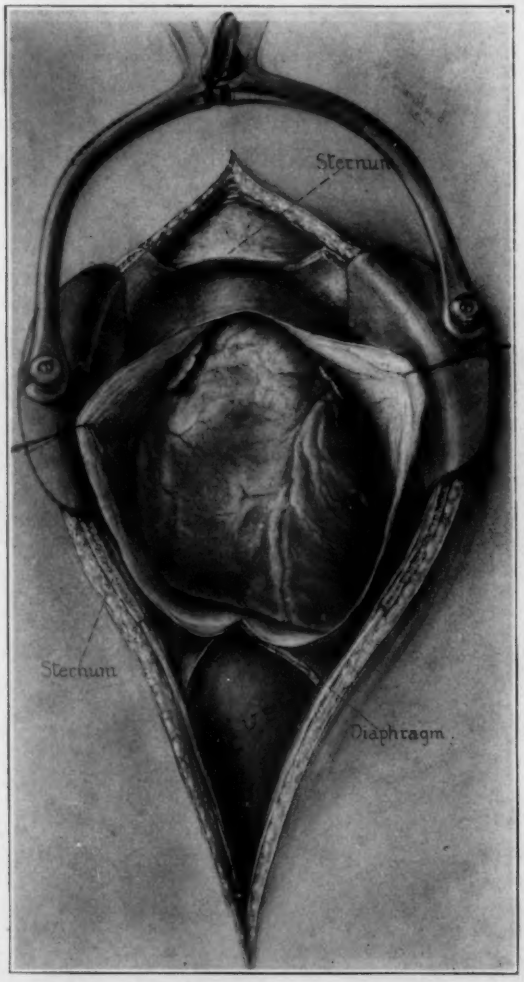

Fig. 3.—Exposure of heart by median sternotomy.

transversely. If the wound lies in the fifth interspace, the intercostal incision should be placed in the fifth rather than in the fourth interspace.

The method has its advantage in that exposure of the left pleural cavity is obtained. It is the method of preference in those cases accompanied by a wound in the left lung from which there is active bleeding.

2. METHODS OF SUTURE

What is encountered when the distended pericardium is opened depends on several conditions. If there was no active bleeding from the wound in the pericardium the bleeding from the wound in the heart may have subsided. Active bleeding from the wound in the pericardium

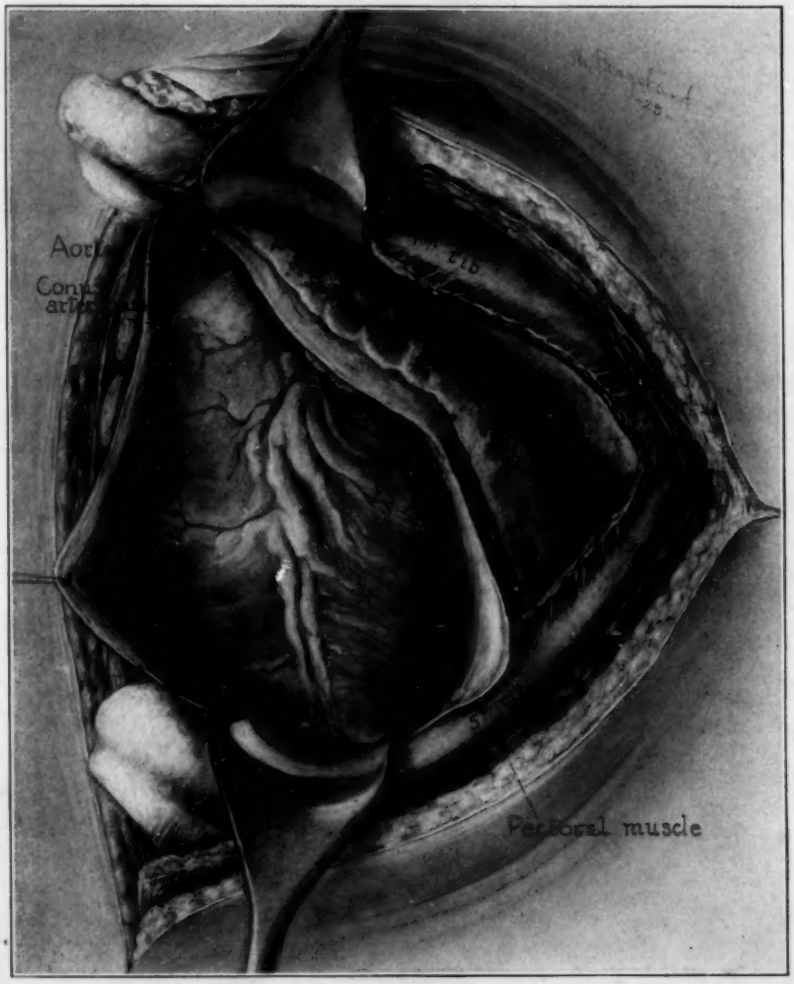

Fig. 4.—Exposure of heart by intercostochondral thoracotomy.

indicates active bleeding within. When the pericardium is opened and the tamponade relieved the heart usually undergoes several forceful contractions; the circulation is improved, and the patient may regain consciousness. The bleeding from a wound in the auricles, while it may be marked, depending on the extent of the wound, is continuous

and usually can be controlled without great difficulty if satisfactory exposure is obtained. If the wound enters the left ventricle or if a coronary artery is severed, the bleeding occurs in spurts that may strike the face of the operator. The following colorful description is given by Matas: [51]

> More often the heart's action is violent and tumultuous, and the field of the operation is deluged with blood, which gushes out in intermittent streams, spurting sometimes beyond the wound in the thorax or folding up into a mass of froth which pours out of the external wound in large quantities. This is especially true of the cases complicated with a large opening in the pleura, which allows the air to rush in and out of the thorax with each respiratory movement and mix with the blood, the heart churning and lashing it into a thick crimson foam which entirely envelops the organ and hides it from the view of the operator. In these imposing circumstances it is impossible to see the wound, much less attempt to suture it. Sponging or mopping is worse than useless. There is but one alternative. The operator must then resolutely do one of two things: he must thrust his fingers into the pericardial sac through the swirl of blood and endeavor to locate the wound by palpating with his fingers and then plugging it with the finger-tips, if he finds it; or he must grasp the heart with his whole hand and drag the bleeding and writhing organ massively out to the thoracic wound, where, by gradually relaxing his grasp, the seat of the hemorrhage will be certainly identified and the suture can be readily applied.

Excluding those cases in which the bleeding is moderate and in which the wound can be sutured as easily as a wound in a striated muscle, there are, in general, two methods that have been utilized in the suture of cardiac wounds.

(*a*) *Compression of the Base of the Heart.*—A method for controlling hemorrhage from a wound in the heart by obstructing the flow of blood by compression of its base was proposed by Sauerbruch [52] in 1907. With the right hand the apex of the heart is displaced anteriorly while the third finger of the left hand is inserted through the great transverse sinus,[53] and the fourth and fifth fingers are placed posteriorly in the pericardial cavity (fig. 5). Included between the third and fourth fingers are the venae cavae with a part of the right auricle and the pulmonary veins. By compression of these structures the flow of blood into the ventricles can be controlled. The thumb and

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51. Matas, Rudolph: Surgery of the Vascular System; Surgery, Its Principles and Practice, edited by W. W. Keen and J. C. DaCosta, Philadelphia, W. B. Saunders Company, **5**:67, 1909.

52. Sauerbruch, F.: Die Verwendbarkeit des Unterdruckverfahrens bei der Herzchirurgie, Arch. f. klin. Chir. **83**:537, 1907.

53. The great transverse sinus in the adult is large enough to admit the surgeon's finger. This can be done without difficulty at operation if it is remembered that lying posterior to the aorta and pulmonary artery is a free passage from one side to the other.

index finger of the left hand are free to steady the heart while the wound is sutured (fig. 6).

It was found experimentally that the heart and the brain could tolerate ischemia for a limited period of time. This period of safety in the dog was one and one-half minutes;[40] in the cat, three minutes,[54] and in the rabbit, three and three-fourths minutes;[55] if the obstruction was continued beyond these limited periods, either the heart failed to recover its normal rhythm or signs of degeneration of the cortical cells

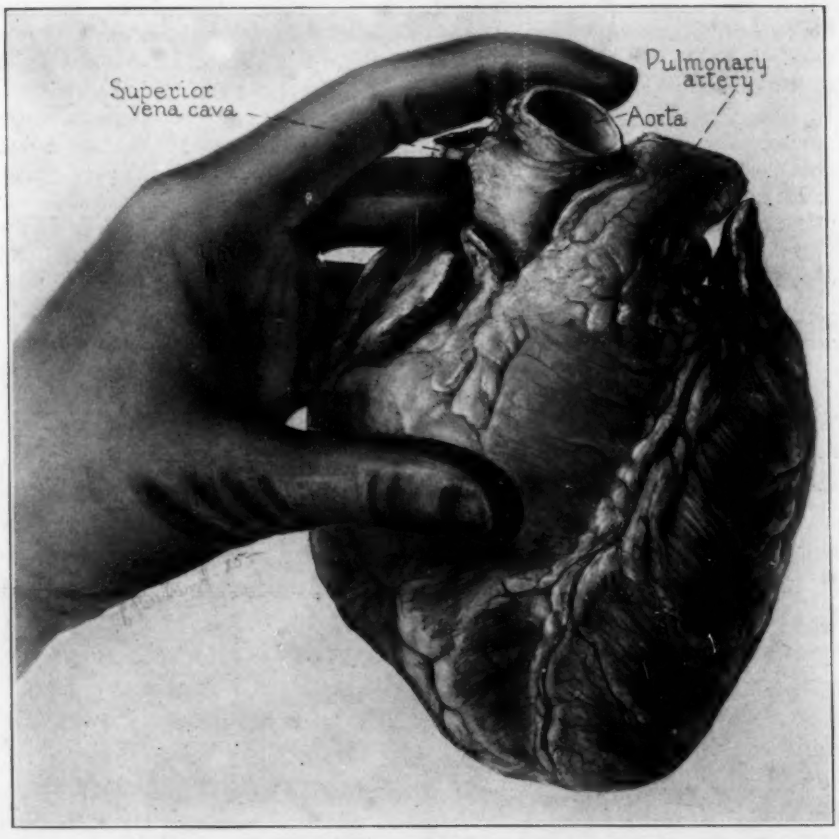

Fig. 5.—First step in method of controlling flow of blood through heart by compression of base: third finger is placed through great transverse sinus; fourth and fifth fingers are placed posteriorly in pericardial cavity; by compression with the fingers the venae cavae and the pulmonary veins can be occluded.

54. Cutler (Footnote 49, fourth reference).

55. Laewen, A., and Sievers, R.: Experimentelle untersuchungen über die chirurgisch wichtigen Abklemmungen des grossen gefässo in der Nähe des Herzens unter besonderer Beruchsichtigung des Verhaltnisse bei der Lungen embolie operation nach Trendelenberg, Deutsche Ztschr. f. Chir. **94**:5, 1908.

developed subsequently. To prolong the period of safety it was suggested that intermittent or only partial obstruction to the flow of blood be effected during the process of suture.

From experiments on dogs Rehn [40] concluded that the method was not safe, but that in certain human cases its application was a necessity. That the ventricles themselves can be grasped forcibly in the hand of the operator and the wound sutured was shown in several successful human cases.

(*b*) *Plugging the Wound with the Fingers.*—To stop the bleeding by inserting the distal phalanx of one or of several fingers into the

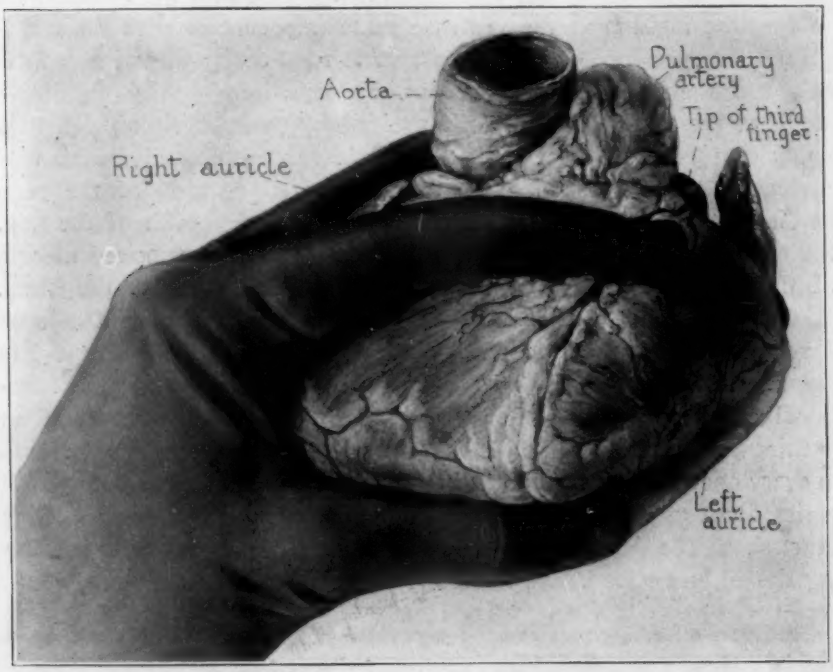

Fig. 6.—Second step in method of controlling flow of blood through heart by compression of base; the heart is steadied between the thumb and the index finger.

wound comes to the surgeon as a conditioned reflex. Moments are thus afforded in which one suture can be placed which, when tied on removal of the finger, helps to control the bleeding. Additional sutures, if necessary, can be placed.

3. DISPOSITION OF THE PERICARDIUM

The handling of the pericardium is an important factor in cardiac surgery. It may be involved in two serious operative sequelae: a

rapidly forming pericardial effusion, which may lead to fatal tamponade [56] and cardiopericardial adhesions, which commonly follow the subsidence of the effusion.

A study [57] of the factors concerned in these sequelae was carried out experimentally with the idea that they might be prevented or their serious consequences avoided. It was shown that operative trauma, infection, and the application of hot salt solution resulted in the formation of effusions and adhesions. The epicardium and parietal pericardium could scarcely be touched at operation without the subsequent formation of adhesions, and if an incision was made in the ventricle, a firm, dense adhesion to the pericardium almost always formed. Adhesions were not prevented by the transplantation of fat into the pericardium so that the incision in the ventricle came into contact with the transplant. The presence of blood in the pericardial cavity was of no consequence in the formation of adhesions.

That these sequelae might be avoided by pericardiectomy led to a study of the necessity of the pericardium for the normal function of the heart. Experimentally, the total or partial removal of the pericardium had no demonstrable effect on the general health of the dog, the response to exercise, or the size of the heart. The incised margin of the pericardium did not become intimately adherent to the heart.

It was concluded from this study [57] that compression of the heart developing as a sequel to operation could be avoided by incomplete closure of the pericardium without appreciable impairment to the functional capacity of the heart. As a precaution against tamponade an opening in the pericardium 1 or 2 cm. in length should be provided in every operation on the human heart. Because of the sensitivity of the pericardium to trauma the presence of a drain is not advisable. The heart should be delicately handled at operation and unnecessary sponging should be avoided. Rigid aseptic technic should be observed.

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56. Rapidly forming postoperative pericardial effusions producing compression of the heart occurred in two cases in which operations were performed for mitral stenosis (Footnote 54). In one case the formation of the pericardial effusion was indicated by changes in the size and shape of the cardiopericardial roentgenogram. It assumed its greatest extent on the third day following the operation, having increased about 2 cm. in its transverse diameter. It then began to decrease in size and this was accompanied by an improvement in the condition of the patient. In the second case extensive fibrous adhesions between the heart and the pericardium were sectioned at operation. At operation the pericardium was closed throughout its entire extent. Toward the end of the postoperative period, which lasted about twenty hours, the patient presented the picture of a failing circulation. The postoperative roentgenogram showed an increase of 1 cm. in the transverse diameter. At necropsy 350 cc. of fluid was found in the pericardial cavity, the rapid formation of which undoubtedly produced a fatal tamponade.

57. Beck, C. S., and Moore, R. L.: The Significance of the Pericardium in Relation to the Surgery of the Heart, Arch. Surg. **11**:550 (Oct.) 1924.

During the postoperative period signs of compression should be watched. Standardized roentgenograms,[58] which permit accurate comparison of the size and shape of the cardiopericardial shadow, are an important adjunct. If compression of the heart occurs pericardiotomy should be performed.

V. EXPERIMENTS

Methods of suturing wounds of the ventricles and of the auricles were tried experimentally on dogs. Under ether anesthesia the heart was stabbed with a long slender knife inserted through the chest and the pericardium, and the operation of suture was performed. The exposure of the heart under aseptic precautions required several minutes during which time variable amounts of bleeding occurred and variable degrees of tamponade were sustained.

It was found in general that wounds of the right ventricle were less difficult to control and suture than wounds of the left ventricle. The ease with which auricular wounds could be sutured depended on the exposure of the wound. If a satisfactory exposure could be provided, the wound could be closed readily with one or two Lembert sutures. In the discussion that follows reference is made only to wounds of the ventricles.

In these experiments it was found that compression of the heart during the process of suture, although capable of making the operative field bloodless, was poorly tolerated. Fibrillation, which in the dog was fatal, occurred in about half the experiments in which compression was used. Other factors in determining the result were the breed of dog[59] used, the degree of tamponade sustained by the heart, the extent of the wound, and the amount of blood lost.

The method of plugging the wound with the finger was utilized in several experiments in which stab wounds were made in the left ventricle. It was found that to control the bleeding by this method frequently

58. Successive roentgenograms can be standardized by having the chest recline at a constant angle, the roentgen-ray target placed at a fixed distance and at a constant angle posterior to the heart, and the plate at a fixed distance and at a constant angle anterior to the heart. For this purpose a special bed, an adjustable plate holder, and an adjustable frame to hold the roentgen-ray tube were used at this clinic. A sheet of canvas was used for the constant support of the chest instead of the ordinary mattress and spring so that it was unnecessary to move the patient in taking the roentgenograms.

59. A marked variation in the ability of the heart to withstand trauma existed in various breeds of dogs. This resistance to operative trauma was greatest in the bulldog and terrier, and least in the chowchow and hound. A simple incision in the left ventricle of the latter was sometimes fatal. The heart of the cat and of the rabbit was more resistant than that of the dog, and the heart of the goat was peculiarly capable of withstanding trauma better than any of the animals named. The human heart also has a high degree of resistance to the immediate effect of operative trauma.

called forth so much pressure on the finger that the cardiac muscle was torn, the wound accordingly enlarged, and the difficulties of the procedure augmented. In several experiments exsanguination occurred before the wound could be sutured. Furthermore, the presence of a finger in the wound added to the difficulty of placing a satisfactory suture. Because of its marked friability cardiac muscle could not withstand inclusion in clamps and forceps, and such instruments should not be applied.

Experience with the foregoing methods for the control of hemorrhage from wounds of the heart was afforded also in the experimental work carried out in conjunction with Dr. Elliott C. Cutler in the development of a method for the surgical relief of mitral stenosis.[60] In these experiments deliberate incisions were made in the left ventricle for the introduction of the cardiovalvulotome, and the unsatisfactory results of controlling these incisions by compression or by plugging with the finger led to the development of another method.

METHOD OF CONTROL SUTURES

When the pericardium is opened a suture to steady the heart is placed in the apex, the wound in the heart being momentarily disregarded. The impulse to control the bleeding instantly by placing a finger on the wound should not be heeded until the apex suture is placed. Unless the heart be steadied, the finger cannot be maintained in position. The apex suture is held under traction between the thumb and the third finger of the left hand, and the index finger is placed on the wound (fig. 7). The bleeding is thus controlled. The movements of the heart are transmitted to the left hand; both move in unison so that the index finger can be maintained effectively on the wound. This can be done regardless of its position on the ventricles. Two control sutures taking a deep bite of muscle are placed, one on each side of the finger at the level of the wound. They are crossed and then held under gentle traction by the assistant as the index finger is removed. The apex suture is dropped. An excellent exposure of the controlled wound is provided and ample time may be taken in placing the permanent sutures (fig. 8). Coronary vessels, if they lie adjacent to the wound, can be avoided in the sutures and a neat approximation can be obtained. The apex and the control sutures are removed.

The heat of the operation is over when the index finger is placed on the wound while the heart is steadied by a firm hold on the apex suture. If the idea be fixed in the operator's mind first to place a suture in the apex, disregarding the wound momentarily, the suture can be

60. Beck, C. S., and Cutler, E. C.: A Cardiovalvulotome, J. Exper. Med. **40**: 375 (Sept.) 1924.

placed in a few seconds and the subsequent procedure becomes remarkably simple. The flow of blood through the heart is not interrupted and sufficient time may be taken to complete the procedure with deliberation. The operator should have noted the position of the wound under the finger so that the control sutures can be placed at the level of the wound. They should be placed also as near the margin of the wound as the

Fig. 7.—New method of suture: control of hemorrhage from wound preparatory to suture; traction on apex suture steadies heart so that index finger can be maintained effectively on wound; a control suture is being placed.

overlying finger allows. Traction on them is most advantageously applied when they are held by the assistant an inch (2.5 cm.) or two from the wound. The traction should not be so strong as to tear through the muscle. If it is found on removal of the index finger that the bleeding is not entirely controlled, the finger may be replaced on the wound and another control suture placed on each side at the point where

the bleeding occurred. The four control sutures, two from each side, are crossed and held by the assistant. In this way a wound of almost any size can be controlled, and a good exposure for placing the permanent sutures can be obtained.

The method was applied successfully in the suture of stab wounds made experimentally in the right or the left ventricle of the dog. It

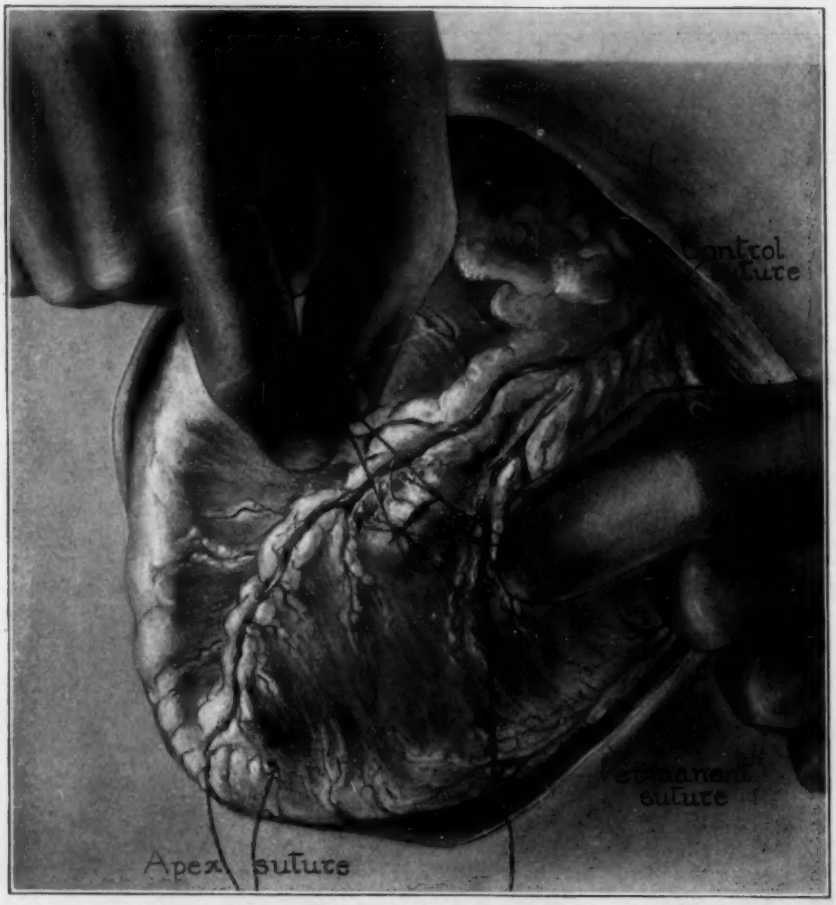

Fig. 8.—Second step in new method: the control sutures are crossed and held under gentle traction by the assistant; hemorrhage can thereby be controlled, and a good exposure of the wound is provided. The permanent sutures can be placed so that adjacent coronary vessels are avoided and a satisfactory approximation of the wound is obtained.

was the method of choice in the control and suture of the incision made in the left ventricle for the insertion of the cardiovalvulotome [60]—an instrument devised for sectioning the mitral valve. It was entirely satisfactory in the control and suture of the incision made in the left

ventricle in two human cases in which operations were performed for the relief of mitral stenosis.

The method has its advantages in that the flow of blood through the coronary and the cerebral vessels is not occluded. It is well tolerated so that ample time may be taken to complete the procedure. An opportunity is afforded in placing the permanent sutures to avoid inclusion of adjacent coronary vessels. A neat approximation can be obtained.

THE MECHANISM OF BACTERIAL INFECTION

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This discussion will deal practically exclusively with infection produced by bacteria of the aerobic variety. I have little experience with the infections produced by anaerobic organisms except as these take part and are found in cases of intrapulmonary suppuration. The little I can say is that, clinically, established infection by anaerobic bacteria is usually produced by mixed infection with more than one organism; that the latter are probably originally secondary invaders and when centered in the foci of pulmonary suppuration are productive of slight or moderate grades of damage, and that when inoculated into a previously uninfected tissue, as happens after operations of the lobectomy type, the resulting pathologic change is extensive and of maximum intensity and results in death in 50 per cent. or more of the cases.

TERMINOLOGY

In medical literature the phenomena of bacterial infection are associated with the usage of the following terms: sepsis, sapremia, septicemia, bacteriemia, pyemia, general infection and general blood infection. Much confusion surrounds the use of these terms owing to the loose way in which they are generally employed. The term sepsis has sometimes wrongly been made to include the term sapremia; this inaccuracy should be avoided altogether. The term sepsis is a generic term and should include all forms of infection by virulent organisms capable, under appropriate conditions, of producing pus. In this sense typhoid infections, etc., are a form of sepsis as well as osteomyelitis, furuncles, carbuncles, etc. Under this definition, sepsis includes all septicemias, bacteriemias, pyemias and general blood infection as described here. The term general infection as it has lately been introduced in the literature is synonymous with sepsis.

Under ordinary conditions an infection is established by a certain type of organism and the course of the infection continues throughout with that organism as the sole cause. Quite commonly, however, the course of an infection is disturbed by an influx of organisms of a different type than those which are originally present. The differences are perceptible in the pathologic and clinical manifestations and are demonstrated in the bacteriologic studies. Added infections of this kind are known as secondary infections and the organisms as secondary invaders. They are particularly prevalent in infections in which wounds are exposed either during dressings or because of the types of treatment employed

(sunlight treatment, for instance); such secondary infections are frequently of no consequence in the clinical progress of the infection. In fatal cases secondary infection is very common just before death, and in these it sometimes assumes the clinical manifestations of a terminal general blood infection.

The two cases that follow are rather striking examples of secondary infection.

CASE 1.—A baby was vaccinated against smallpox in the usual way on the arm. The resulting lesion did not heal in the way these inoculations usually do; but instead grew larger and became more excavated, and the base of the ulcerated area became covered with a brown crust. Finally, the cause of this abnormality in the behavior of the vaccination was proved to be a secondary infection with diphtheria bacilli; these organisms were demonstrated in smears taken from the discharge from the ulcer. The patient promptly recovered after the proper administration of diphtheria antitoxin.

This case was published by Roosen Runge:

CASE 2.—A patient was admitted to the hospital with a left metapneumonic empyema. A blood cultivation made before operation was sterile. The pus in the chest contained pneumococci. Eight days after operation, physical signs of a right pleural exudate became evident. Two days later, the discharge from the operated empyema cavity became hemorrhagic. One day later, a blood cultivation demonstrated 30 colonies of diphtheria bacilli per cubic centimeter of blood cultivated. Cultures of the discharge and of the exudate from both sides showed diphtheria bacilli also. Two days thereafter the patient died. The postmortem examination showed an endocarditis and cultures made from the heart valves resulted in a growth of diphtheria bacilli also.

The term sapremia is understood to indicate a condition in which a focus of decomposition is present in the body the chemical products of which are absorbed into the blood and lymphatic circulations of the body and produce constitutional symptoms. The decomposition takes place in circumscribed tissue which having become dissociated from the rest of the body, as far as its biologic connections are concerned, becomes for practical purposes a foreign body; the most typical example of this is the retained placenta after childbirth. The bacteria giving rise to this decomposition belong to the saprophytic group of organisms and are characterized by their inability to invade living tissue as a part of, and in intimate relation with, the rest of the living body, that is, by a lack of virulence. Living organisms of this group are never found in the blood stream, not because they do not pass into the circulation but because the bacteria destroying powers of the host are always sufficiently active to cause their immediate disappearance.

The term septicemia implies a condition in which a local lesion is present owing to the invasion of a body tissue in intimate biologic connection with the rest of the body, by virulent bacteria. Poisonous toxic

bodies result from the growth of the organisms which, being absorbed into the body circulation, spread throughout the body and give rise to constitutional symptoms. Confusion exists in differentiating between cases in which bacteria can be demonstrated as being present in the blood and those in which they are absent, and the term septicemia has been loosely applied to both, especially when the histories of cases are given. The definition and use of the term has even been confounded with that of the term pyemia. The terms general blood infection or general infection, which have lately come into use, have been employed practically as an equivalent of septicemia, and have come to mean a bacterial infection of the body with or without demonstrable local lesions in which living organisms can be demonstrated to be present in the circulating blood by the usual cultural methods. According to some, septicemia is distinguished as a condition in which the organisms are multiplying in the blood circulation.

The term pyemia is an old one and a good deal of confusion has surrounded its usage and still does. If the term is to be employed at all it seems best to restrict its usage to infections of the body in which more than one lesion is present and in which it can be established that one of these is the original portal of entry for the infection, and that the others result from the transmission of the infecting agent from the latter or that all of the lesions are secondary to an obscure or demonstrable healed primary lesion. The original portal of entry is usually designated as the primary lesion; the other lesions are secondary, subsidiary or metastatic lesions to the primary focus. The term pyemia is used equally often in conditions in which bacteria are demonstrated to be present in the blood and in those in which they are absent, in cases in which there are few bacteria in the blood and in those in which the organisms are multiplying in the circulation; in these aspects the definition of the word is confused with that of septicemia.

It seems best to avoid the use of this confusing terminology and to make a much more simple classification of the phenomena of infection on the following basis; this will be employed here and in other articles.

1. The term infection will be used as a generic one and will include all of the phenomena of a bacterial attack on tissue, organ or the entire body. The various kinds of infection will naturally be described in accordance with the tissues, organ or part of the body involved, and in accordance with the organism or organisms encountered; thus, saprophytic infection of the uterus, staphylococcus infection of the skin, or streptococcus infection of the liver, etc. When no other modifynig term is employed it is to be assumed that cultivations of the peripheral blood taken during life are sterile. The differentiation commonly made between local and general infection theoretically does not exist, and the

terminology is one more of convenience than of accuracy. Local infections must necessarily involve some degree of general constitutional reaction and general infections must necessarily find their beginnings in, or be associated with, a local focus of infection. As far as possible this differentiation will be avoided or made clear in the text whenever it must be used.

2. The term "bacteriemia" also will be used in a generic sense to indicate any condition in which bacteria can be cultivated from the peripheral blood during life. The various kinds of bacteriemia also will naturally be described in accordance with the organism found; thus staphylococcus bacteriemia, streptococcus bacteriemia, etc.

3. The term "general blood infection" will indicate a subgroup of the generic term bacteriemia and in this and in articles to follow a distinction will be made between the terms bacteriemia and general blood infection on the following basis: The term bacteriemia is meant to imply a condition in which the organisms demonstrable in the circulating blood by the usual cultural methods are derived from a local lesion somewhere in the body, are usually small in number, and the faculty of destroying the circulating bacteria is more or less retained by the appropriate antibodies of the blood. The term general blood infection is meant to imply a condition in which, in addition to the foregoing, a multiplication of the bacteria takes place in the circulation and the faculty of destroying the circulating bacteria is more or less lost by the appropriate antibodies of the blood.

Under appropriate circumstances both of these groups of terms will be employed together; thus, staphylococcus infection of the skin with staphylococcus bacteriemia or general blood infection. The character of the local lesion in the complete development of any individual infection is best described by the use of the terms primary or secondary (metastatic, subsidiary); thus, primary staphylococcus infection of the skin with staphylococcus bacteriemia, or primary streptococcus infection of the tonsil with secondary streptococcus infection of the appendix, etc., the absence of any descriptive bacteriemia indicating that a cultivation of the peripheral blood made during the course of the illness was sterile.

CLINICAL DISTINCTION

A distinction between cases of infection made on the basis of the presence or absence of living bacteria in the peripheral blood is clinically a most important one. Theoretically the distinction does not exist. It seems fair, from all the available evidence, to assume that in every case of infection, whether it be mild or severe, organisms are entering the circulation. In the cases in which cultivations of the peripheral blood made during life are sterile it should be assumed that the organisms

which reach the circulation are immediately destroyed in some way or other by the appropriate protective agencies. A bacteriemia or general blood infection exists only when the bacteria destroying agencies are partially or wholly lost, or inhibited. The bacteria destroying power may be lost or inhibited for only short periods of time and the bacteriemia accompanying such a state is spoken of as a temporary one.

In clinical practice infection of the human body appears in one of the following forms:

1. A local lesion is present apparently without any constitutional symptoms. This must necessarily mean that the amount of constitutional disturbance is so small as not to be perceptible to the affected person or recognizable to a competent examining physician. The best examples of this type are the small furuncles that occur on the back of the neck.

2. A local lesion is present with general constitutional symptoms. The latter show an infinite number of variations both in degree and in kind, and the manifestations may be very severe and may terminate in the death of the individual. Positive blood cultures are not demonstrable.

3. Cases similar to those in Group 2 but in which living organisms can be demonstrated in the circulating blood. The bacteriemia may or may not be a temporary phenomena; the organisms may be present in the blood in cases that go on to recovery and may disappear from the circulation in cases that later end fatally.

4. Cases in which secondary lesions appear. Living organisms may not be demonstrable in the circulating blood, or may be demonstrable as a temporary or permanent phenomenon; may be present in comparatively small or in overwhelming numbers; may be demonstrable in cases that go on to recovery, and may be absent during the entire course of the illness in cases that go on to a fatal termination.

5. Cases in which a bacteriemia exists but in which a local focus is not demonstrable. The term cryptogenetic sepsis has been applied to this form of infection but present day knowledge makes it advisable to abandon as misleading the use of this term. Under the last terminology cases of bacterial endocarditis had previously been included because a primary focus was not demonstrable.

As an explanation of the latter phenomenon—absence of a primary focus of infection—it has been assumed that it is possible for bacteria to pass through a body surface. For this purpose the surface of the body is not only the external skin but also the mucous membrane lining the entire extent of the alimentary canal, the entire lining membrane of the urogenital tract and of the pulmonary system. The epithelial lining of the ducts and the alveoli of all glandular structures in direct connection with any of these tracts is also an external surface of the body as

far as the introduction of infection is concerned. The conjunctiva of the eyes is also an external surface. This is but an extension of the universal law throughout living matter that no relation can exist between living matter and its environment except through its surface.

MECHANISM OF INFECTION

There is a continuous contact between the various surfaces of the body and bacteria of all kinds. It seems to be true that, even during states of health, traumas of one kind or another are constantly occurring to the major surfaces of the body—the skin or the intestinal mucosa—and that through these breaks bacteria of one kind or another are constantly entering the body. The protective forces of the body are, however, so well balanced, arranged and strongly developed that interaction of bacteria or of their biologic products and surface cells is prevented or, what is more often the case, the effects of this interaction are immediately neutralized and the bacteria that enter are immediately destroyed. No perceptible effect is demonstrable in the body cells, organs or tissues either immediately or subseqently, and the condition of health continues undisturbed. The balance between the attacking powers of the bacteria —their virulence—and the protective agencies of the body is a constant one during health.

PRESENCE OF TRAUMA

I am strongly of the opinion that the assumption sometimes made, that bacteria can pass through an intact healthy body surface, is an incorrect one. I believe, as far as the external skin and the mucosa of the alimentary canal are concerned, that no entry of bacteria can take place without the intervention of some trauma, however minute it may be. Even in the presence of trauma, it is only in extraordinary instances that the natural protection breaks down and disease ensues, either because the opposing bacterium is one of extraordinary virulence, or because the character of the infection is one to which the natural antibodies have previously, either in the individual himself or in his race, been not at all, or insufficiently, developed. Anthrax infection and the incidence of unaccustomed diseases in savage, aboriginal or other similar races make excellent examples of this point.

It seems much fairer to assume in cases of bacteriemia or general blood infection with obscure etiology that a primary lesion of some kind always exists. This may be in an inaccessible part of the body, e. g., the folds of the intestines, where it can readily escape demonstration, or, if on an exposed and readily accessible location, it may have healed without leaving traces recognizable to the unaided eye before the subject came under observation; and having been of a most inconsequential nature and size, it had entirely escaped the notice of the person himself.

In any case, therefore, of such obscure forms of infections it should not be hastily assumed that a primary lesion did not exist, but rather that human deficiency is not capable of demonstrating the initial lesion in all cases.

In the deep tissues and in secondary lesions, trauma need not necessarily be a gross mechanical thing although, true enough, even here such trauma frequently exists and it is no uncommon thing in an established bacteriemia or general blood infection to witness abscesses form in the depths of a muscle or between the facial planes following a slight blow. Other forms of trauma are equally operative, chemical forms, thermal forms, etc. Any form of trauma produces either qualitative or quantitative inhibition of the vital cellular processes: (1) by actually destroying the molecular composition of the cells and with this their morphology; (2) by the development of chemical inhibitory bodies that inhibit or neutralize intracellular chemical reactions necessary in the life of the cell; (3) by deprivation of the normal food supply of the cells or tissues; (4) by favoring the accumulation of poisonous metabolic bodies; (5) by destroying fundamental physical cellular connections in cell groups accustomed to live together and dependent one on the other, leading in turn to disturbances in food supply, to abnormal accumulations of excrementitious matters, to incoordination, etc.

The most important mechanisms are mechanical trauma—even a strain or sprain is a sufficient trauma—and disturbances of nutrition of the cells. In trauma cells are exposed which are not prepared to withstand the attack of bacteria. In any case, trauma or lack of food supply, the actual result of the disturbance so far as infection is concerned is to produce tissue on which the bacteria can grow and in which bodies deleterious to the life of the bacteria cannot develop, or develop in such insufficient quantity as to be negligible. The most common mechanism for causing interference with the nutrition of the cells, organs or tissues is thrombosis and embolism, either of which by plugging a vessel deprives the intercepted territory of its main source of food supply. This will be gone into in detail in a later part of this article.

SURFACE INFECTIONS

Surface infections of the skin have intimate relations with the sweat glands and hair follicles, and obstruction to the outflow of any excretions from these passages is the most common immediate cause for the development of an infection. Surface infections of the intestinal tract have intimate relations with accumulations of lymphadenoid tissue. The most important of these are the tonsillar accumulations in the pharynx and those in the lower end of the ileum, Peyer's patches. Surface infections in glandular structures in connection with the alimentary canal, the liver,

pancreas, etc., are usually continuations of surface infections in the neighboring portion of the alimentary canal and are frequently associated with relative or absolute obstructions to the outflow of the gland secretions, such as are produced by the presence of stones or by spasm of the sphincter muscle at the outlet, produced by abrasions, etc. Surface infection at any junction of the skin and mucous membrane, e. g., the breast nipples or the anus, is most frequently, if not always, connected with trauma and the formation of fissures, which are especially prone to occur at this point because of mechanical trauma, such as suckling of the infant or passage of hard scybala.

Obstruction to the outflow of excretions of a glandular organ results in a damning back of secretions which in turn exerts an interference with the metabolic activity of the secreting cells. According to our definition previously given, this is a form of trauma.

Infection developed in any of these ways in a glandular organ can progress in one of two ways:

1. The infection remains centered in the gland lumina. A single abscess develops which when properly incised heals without any further progression of the inflammatory infectious process. In the breast this form is not as common as the second variety. The typical example of this form of infection in the liver is the amoebic abscess.

2. The development of the infection is communicated with the lymphatic channels and a typical form of lymphangitis develops. Multiple abscesses are the rule. This is the usual form of breast abscess, and in the liver it is the form usually seen with all types of infection except that caused by the ameba. It is possible for both of these forms of infection to coexist.

Infection of the urogenital tract is most freqently communicated by direct contact and is probably most often originated in minute traumas during intercourse. Progression of the infection occurs (1) by continuity along the surface; (2) through the lymphatics, and (3) by metastasis.

Infection of the pulmonary surface is most often associated with disturbances of the circulation, most frequently produced by chilling. With pneumococcus infections, progression of the process occurs by continuity along the surface; with certain other organisms penetration below the surface occurs and tissue becomes destroyed.

All these surface forms of infection are primary foci and in each case they act as portals of entry for the infecting organisms into the body system. Infection in a solid organ—such as bone or brain—or in tissue —such as muscle or connective tissue—not exposed on any surface of the body cannot be a primary affair, except in those instances in which excessive forms of trauma, such as compound fractures, lacerated, incised

or punctured wounds, cause communications between the depths and the surface. Except for this, infections in such organs or tissues are metastatic affairs.

Infections of the body cavities, such as the peritoneum, the pleura or the meninges, are practically always continuations of infections in adjacent organs and are produced either by rupture of a hollow viscus, e. g., perforating appendicitis, or by continuation of the process through the lymphatics of the primarily affected organ, or by contiguity of an inflammatory process with the endothelial lining of the hollow cavity. In rare instances infection of these hollow cavities is metastatic. In women peritoneal infection can be a primary infection and frequently occurs by continuity through an open fallopian tube.

Absorption of bacterial toxins from any primary lesion occurs by way of the lymphatic system and by way of the blood stream. Penetration of the infecting bacteria into the body occurs also either through the lymphatic stream or through the blood stream. Both forms of communication are always necessarily present in all forms of infection. In certain classes of infection, especially those of the skin, and of the distal parts of the extremities, the preponderance of the lymphatic form gives rise to the typical clinical picture known as lymphangitis. In the latter form of infection the progression of the process from its portal of entry is a continuous one along the lymphatic channels, and the spread of the infecting bacteria into the body is a continuous penetration and growth along the lymphatic channels. Infections entering through accumulations of lymphadenoid tissue, notably the tonsils and Peyer's patches, are typical forms of lymphangitis as thus defined, and the progression of the infection along the lymphatic channels can be frequently demonstrated clinically in the secondary involvement by continuity of the regional lymph nodes in connection with these surface areas. In all forms of lymphangitis it is not possible to cultivate living organisms from the peripheral blood stream during the duration of the infection.

VENOUS THROMBOSIS

Communication of the infectious process and penetration of the infecting organisms from the portal of entry into the rest of the body by the blood stream is intimately associated with the subject of venous thrombosis. The inflammatory process associated with any infection has as one of its prominent characteristics the slowing of the blood stream and the formation of venous thrombosis. Under suitable circumstances the growth and multiplication of the bacteria in the focus of infection finally result in their penetration into the vascular channels, where in a relative way they are blocked from further progression, at least temporarily, by the occluding thrombus. However, the bacteria find an

excellent culture medium here, and unless their powers of further growth and development are destroyed by the natural forces of the body, they continue to multiply and to penetrate the clot until they reach the surface of the thrombus, where the bacteria come into contact with the freely circulating blood in a connecting channel. A number of possibilities develop as a result of this biologic progression:

1. The thrombi form a sufficient barricade and successfully localize the bacteria away from the circulating blood. Under such conditions no bacteria can be demonstrated in cultivations of the peripheral blood.

CASE 3.—A patient was given a transfusion during the course of a severe anemia. Following this the vein employed for entry became thrombosed and it was distinctly felt as a thickened cord at the bend of the elbow. This gradually became inflamed and an abscess formed. Healing followed promptly after incision and drainage of the latter. There were never any constitutional symptoms or other evidence to indicate that a bacteriemia was present, and cultivations of the peripheral blood remained sterile.

2. The growth of bacteria on the surface of the thrombus in contact with the circulating blood results in numbers of the bacteria being thrown off into the blood stream. The number [1] of organisms thus cast off into the circulation is relatively and actually small. In some cases the bacteria destroying powers of the blood are sufficient to kill the organisms as fast as they are thrown off, and in these cases positive blood cultures are not obtained. In other cases the bacteria destroying powers of the blood are only sufficient to kill the organisms a little less quickly than they are shed into the circulating blood. Positive blood cultures are then obtained but the number of organisms demonstrable in the peripheral blood remains small and the bacteria do not appreciably increase in numbers in successive blood cultivations. In practice recovery is possible from such forms of bacteriemia. The best examples of this are the milder bacteriemias associated with osteomyelitis and the cases of sinus thrombosis after middle ear infection with mastoid involvement.

CASE 4.—A patient had had a cholecystectomy done two years before admission. The healing of the wound was a most complicated affair and was marked by the development of an intra-abdominal abscess; for a time a fecal fistula also was present. Finally, healing took place and the patient was discharged from the hospital well.

Two weeks previous to the present admission the patient developed pain in the right side of the chest and a hacking cough; there was moderate fever and chilly sensations. Physical and roentgen-ray examinations demonstrated that there was considerable fluid in the pleural cavity and the aspirating needle showed that the fluid was pus. The usual thoracotomy was done and the chest was drained.

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1. The number of organisms is estimated by making the blood cultivations according to the plate method. Each demonstrable colony corresponds to one organism in the circulating blood. The method is accurate for practical clinical work.

There was good immediate reaction; the temperature dropped and the amount of discharge was about what one ordinarily sees. Within several days, however, the discharge increased markedly and became foul; later it became distinctly fecal. The general condition of the patient deteriorated rapidly and for a while it looked as if a fatal issue was impending. Fortunately, however, this was temporary. The amount of discharge gradually lessened; the wound began to heal; the general condition progressively improved. Healing finally occurred and the patient was discharged well. This was probably a residual infection from the first operation two years ago and the suppurating focus worked its way through the diaphragm and into the thorax.

Coincident with the marked increase in the discharge and with its assuming a fecal nature, the temperature assumed an up and down course from 99 to 104 F., with daily remissions. There were numerous chills. At the end of the second week after operation and at the beginning of the third week, cultivations of the peripheral blood on several occasions showed small numbers of colonies of *Staphylococcus aureus*. A culture taken subsequently was sterile.

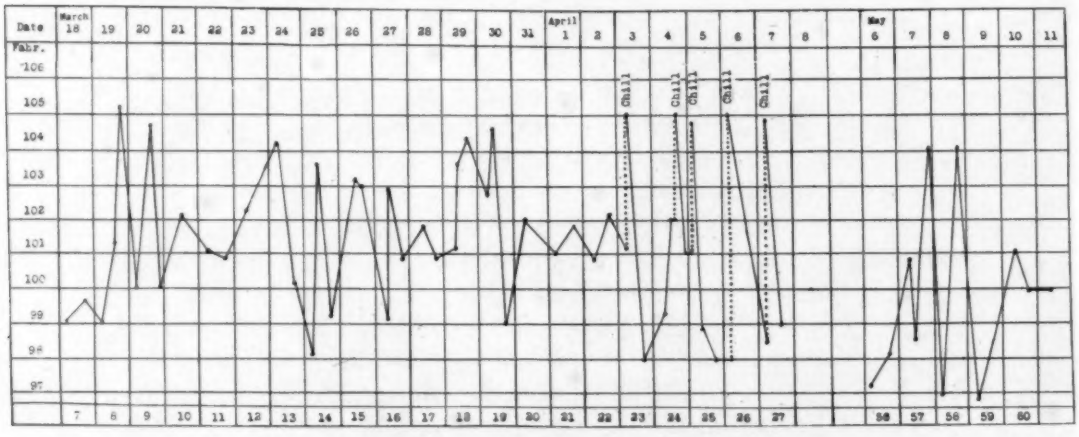

Fig. 1.—Temperature curve in Case 4.

The demonstration of a positive blood culture is explainable on the basis of the presence of an infected thrombus somewhere in the confines of the wound—possibly in an area of necrotic bone—which was in communication with the free circulation, so that organisms could readily find their way into the blood stream.

3. The growth of the bacteria on the surface of the clot in contact with the freely circulating blood is unhindered by any bacteria destroying powers and the organisms accumulate rapidly in the blood. In this form also the bacteria multiply in the blood stream itself. These cases are hyperacute forms of general blood infection and are almost invariably fatal. The commonest example of this is the fulminating form of general blood infection associated with severe forms of osteomyelitis and infections by the bacillus of anthrax.

CASE 5.—A child was first seen at the height of a fulminant acute infection with hyperpyrexia and a demonstrable focus in one clavicle. At operation the entire clavicle was excised in an attempt to remove the cause, the entire focus. The first cultivation of the peripheral blood showed 10 colonies of *Staphylococcus aureus* per cubic centimeter; one taken on the following day showed large numbers of colonies. Death occurred forty-eight hours after operation and the postmortem examination showed a widespread cellulitis of the neck and furuncles in the myocardium.

This case illustrates the usual course of affairs in a fulminant hyperacute case of infection with general blood infection.

These three descriptions do not portray distinct varieties of infection with and without bacteriemia. They indicate stages only in the development of the complete forms of general blood infection. The first passes into the second and then into the third. In clinical medicine

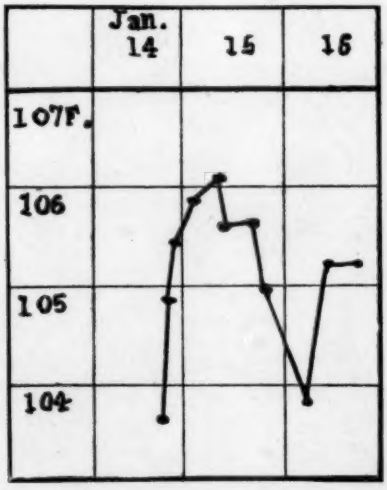

Fig. 2.—Temperature curve in Case 5.

and surgery regression is possible in any of the first two stages to complete recovery. Recovery from the third stage is apparently never seen. Cases that reach the third stage are uniformly fatal; cases in the other two stages may be fatal, especially when secondary lesions begin to form. Prognoses made during the first or second stage can be favorable with or without reservations; those made in the third stage must be unfavorable.

FORMATION OF SECONDARY FOCI

Under any of these three conditions the thrombi in the focus of infection contain living bacteria. Under any of these three conditions pieces of the original thrombus break off and are swept away in the circulation to all and any distant or near part of the body. Such

emboli form the cause of any and all secondary lesions. It is also possible for the bacteria alone floating in the circulation to become arrested at any point (for reasons which will be taken up in detail shortly) and to give rise to secondary lesions. Bacterial emboli, that is, clumps of agglutinated bacteria, also occur and act similarly.

The secondary foci are determined by the arresting of emboli at some point or points of the vascular network; these emboli are primarily, or become secondarily, infected. The actual point depends sometimes on an external trauma but more often on chance than on anything else and is decided by the physics of the local capillary circulation, or on the anatomic peculiarities of the local vascular network. Various pathologic pictures result, depending on the organ or tissue in which the embolus lodges, the size of the plugged vessel, the relative position of the plug, the facility and faculty for vascular anastomosis and collateral circulation in conjunction with the character and virulence of the organisms, and the general powers of resistance of the subject as a whole. Most typical pictures are obtained in osteomyelitis and in the metastatic furuncle of the lung. The dominant characteristics of the pathologic pictures of the secondary foci are (1) a thrombo-arteritis or thrombophlebitis, and (2) more or less necrosis consequent to disturbance of the local circulation. In certain tissues, such as bone, the necrosis plays a dominating rôle in determining the pathologic picture; in certain others, as in the lung, this is a negligible factor.

Sittmann reports the following case:

Case 6.—A girl, aged 20, developed a prepatellar abscess; later this was complicated by an erysipelas. Eight days before death *Streptococcus hemolyticus* was demonstrated in the blood. After death, an examination of the body showed: (1) a right empyema; (2) a right axillary abscess; (3) periphlebitis and thrombosis of the axillary and jugular veins; (4) a paranephritis; (5) a parastrumitis, and (6) a suppurative arthritis of the left ankle.

It is most likely that the infected thrombus in the axillary and jugular veins gave rise to the bacteriemia.

Case 7.—A patient was admitted to the hospital with the history typical of an acute attack of appendicitis; no previous attack had ever been present. Figure 3 shows a preparation of the appendix removed from this patient. The distal two-fifths of the appendix was totally gangrenous and there was a sharp line of demarcation between the gangrenous and the healthy portions of the specimen. The lesion was evidently a thrombo-embolic one. The appendicular vessels were first thoroughly irrigated in order to remove any contained blood, and it was noted that clear fluid escaped from the veins at the conclusion of the irrigation. The vessels were then distended with a solution impervious to the roentgen ray. Thereafter the appendix was fixed and finally cleared in essential oils. The preparation,[2] to the naked eye, shows the entire blood supply of the appendix, of which Figure 3 is an exact reproduction. The illustration

2. The specimen was prepared according to a method devised by Dr. Louis Gross. I am indebted to Dr. Harry Koster for Figure 3.

shows exactly where the blood supply was blocked. Collateral circulation is being established as shown by the fine anastomoses. This is a fine example of a secondary thrombo-embolic lesion during the course of an infection and illustrates the formation of a fixation point.

In any given environment of the body in which secondary foci may form, the anatomic arrangement of the vascular network can only be one of two:

1. In the one, more or less abundant provision is made for compensatory circulation around the arrested embolus. Under such circumstances the focus is quickly and sharply delimited and the extent of the resulting pathologic change is comparatively small; little or no necrosis occurs to increase the amount of destruction.

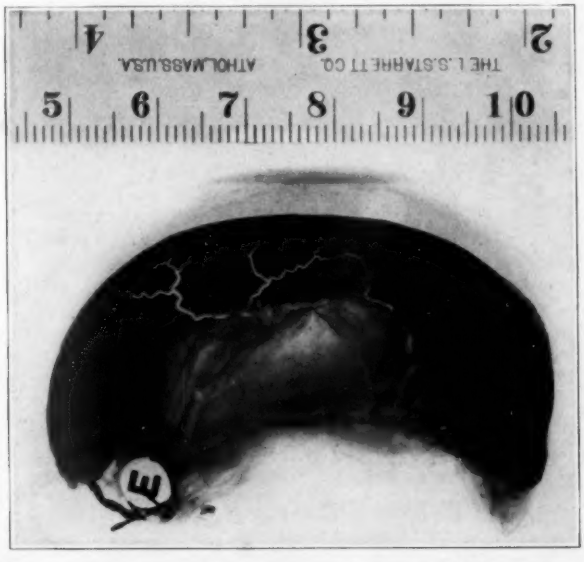

Fig. 3.—Newly formed bone, involucrum (shaded portion) around sequestrums, *A* and *B;* practically entire shaft was destroyed.

2. In the other, the provision for collateral and compensatory circulation is negligible or entirely absent around the arrested embolus. Maximum necrosis then takes place and the action of the bacteria in the embolus, their growth and spread into the necrotic tissue is unlimited; maximum destruction results. These forms are constantly occurring in clinical surgery and one need only indicate the gross characteristics of the pathology of a few as examples: the circumscribed furuncle of the lung, where abundance of circulation, compensatory and other, is the rule; the rapid necrosis and destruction of an entire diaphysis of a bone, in which the nutrient artery is plugged by an infected embolus and where compensatory circulation is negligible; the cutaneous petechiae;

etc. Each individual organ or tissue shows modifications of the pictures here described in accordance with its intrinsic structural peculiarities.

Figures 4 and 5 show the extent of variation in the faculty for collateral circulation and the relations of the latter to destruction of tissue. Figure 4 is a diagrammatic representation of secondary foci of infection in the lung observed postmortem. An attempt is made to show the relative proportions of the several foci and the rest of the lung. Figure 5 is a tracing taken of a roentgenogram in a case of osteomyelitis.

Fig. 4.—Diagrammatic representation of relative area of tissue involved in a territory well supplied with collateral circulation; comparison should be made with Figure 5.

Complete necrosis of the diaphysis eventually took place. The first of these two cases illustrates the minimum of destruction owing to abundant collateral circulation, and the second the maxium of destruction because the fixation point was in the nutrient artery and no collateral circulation was possible.

Comparison of these figures should be made with Figure 6, which shows an injection specimen of the liver. The picture reveals the

immensity and complexity of the vascular network of the liver. The possibilities present here for the formation of metastatic deposits should be considered and these possibilities compared with what one actually sees postmortem in cases of multiple liver abscesses of nonamebic origin. I am indebted to Dr. Gross for Figure 6.

Fig. 5.—Sketch from roentgenogram showing maximal amount of tissue necrosis which results when the thrombus-embolus formation is located in the nutrient artery of a bone and when little or no collateral circulation is possible; comparison should be made with Figure 4.

The physical characteristics of any secondary focus soon become similar to the primary lesion and vascular thromboses become important parts of the pathologic picture. All the characteristics of the primary lesion described here, as regards the presence or absence of bacteriemias

or general blood infections, and as regards the breaking off of secondary emboli and the formation of subsidiary foci, appertain just as readily to any secondary lesion, so that in actual practice any secondary lesion may in turn assume the characteristics of the primary lesion and become a secondary point of distribution for foci subsidiary to itself. The parallel continues to numerous or indefinite generations and the best example of the possibilities occurs in osteomyelitis with its numerous foci, occurring simultaneously or subsequently, in a short space of time or in periods extended over years in the same bone or in different bones.

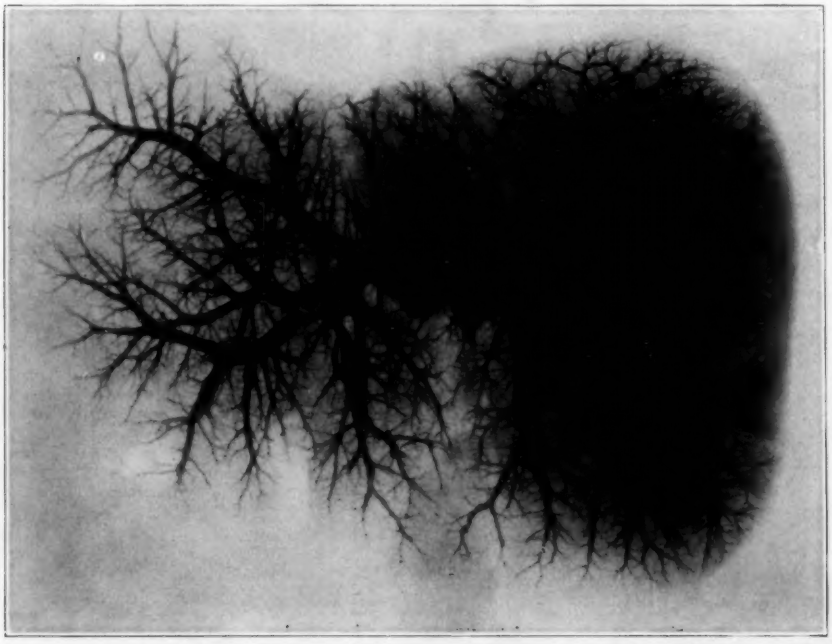

Fig. 6.—Injection specimen of liver described in text; courtesy of Dr. Louis Gross.

There is no experimental, clinical or other evidence nor any practical test that helps in classifying multiple foci developing during the course of an infection. It is perfectly possible for the primary lesion to form the origin for every secondary lesion that ever develops; and on the other hand, it is just as possible for any subsidiary focus, secondary or other, to in turn form a point of distribution and cause either some or all of the succeeding foci that subsequently develop. Sometimes it has seemed possible to distinguish the focus of distribution from purely clinical observation. Several foci are present and these are either in a healing state or have become healed. Subsequently the process relights in one of these and coincident with this exacerbation other new foci

develop. The fact that one of the older foci is in "active eruption" has made me feel that it in turn has become a point of distribution for the new ones.

CASE 8.—The notes of this case illustrate the difficulties in classifying the various lesions that can develop. Twelve days after the birth of a child and following the manual delivery of the placenta, chills and fever developed. Thereafter there developed in succession a femoral phlebitis, a pneumonia, an abscess of the leg and, last, an osteomyelitis of the upper end of the femur and an arthritis of the hip. Streptococci were the cause of the infection and the cultivations of the peripheral blood remained sterile. The relationships of the various foci that developed are subject to many possibilities.

CASE 9.—During the course of a pneumonia a femoral thrombophlebitis developed. After an initial subsidence of the symptoms and signs referable to the leg and during the convalescence of the pneumonia there was renewed activity in the femoral thrombophlebitis as evidenced by pain and fever. The patient died quite suddenly with well marked evidence of an intracranial embolism. Undoubtedly in this case the femoral and not the pulmonary focus was the point of distribution for the intracranial embolism.

PRESENCE OF BACTERIEMIA

A bacteriemia is not always demonstrable at the time a lesion is acting as a point of distribution and secondary and subsidiary foci appear when a bacteriemia is not present. Commonly this is so because the infecting bacteria are being transported in the emboli until they are caught and arrested at one or more fixation points, or, rarely, because the embolus was sterile; also, because the bacteriemia may have been a temporary one and the blood cultivation may have been made at a moment after the bacteriemia had disappeared or when bacteria were temporarily not present in the peripheral blood; whereas at other moments a blood cultivation, if made, would demonstrate the organisms. Technical errors on the part of the person making the blood cultivation may also be at fault.

CASE 10.—A patient was admitted with a fully developed follicular streptococcus tonsillitis and with the signs and symptoms of an acute lesion in the right iliac fossa. A gangrenous appendix, with considerable seropurulent peritoneal exudate from which streptococci were cultivated, was found at operation. The abdominal lesion was undoubtedly secondary to the tonsillitis, but the blood culture remained sterile. The patient recovered.

CASE 11.—A patient was operated on for inflamed gangrenous hemorrhoids. The usual excision operation was done, and it was noted that all the vessels were thrombosed. A low grade temperature developed. On the fourth day the patient became jaundiced and there was some slight tenderness over the liver. The primary lesion was in the thrombosed hemorrhoids and a secondary thromboembolic lesion of some kind developed in the liver. The blood culture was sterile. The liver lesion was apparently not very severe, probably owing to the small size of the embolus or the abundant collateral circulation of the liver. The patient recovered.

Temporary bacteriemias frequently occur after, and are caused by, the dressings of certain classes of wounds, especially those of bone, and are occasionally demonstrable.

In the following two cases it was possible to demonstrate temporary forms of bacteriemias which followed dressings of the wound.

CASE 12.—A patient had previously been operated on for multiple abscesses of the liver and during the course of his illness repeated blood cultures were entirely sterile, except for one on the forty-first day after operation. A blood cultivation of the peripheral blood had been made within an hour after the dressing and showed several colonies of *Staphylococcus aureus*. The sterility of the many blood cultivations made and the fact that previous experience had shown that liver abscesses do not give positive blood cultures go to show that the phenomenon was a temporary one and was due to the dressing of the wound (Fig. 8).

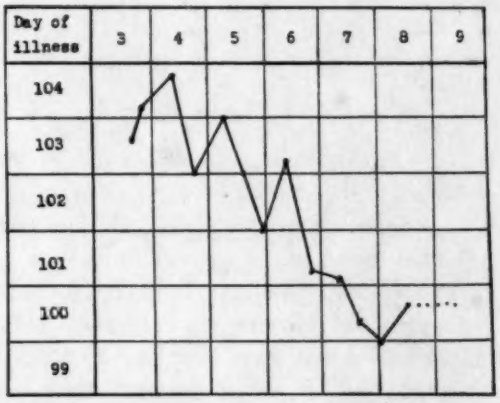

Fig. 7.—Temperature curve in Case 10.

CASE 13.—A patient had been operated on previously for an osteomyelitis of the femur. By the end of the second week the wound looked healthy; there were no other foci demonstrable; the fever was practically at the normal level, and there was no reason to suspect a bacteriemia. A blood cultivation, which was accidentally made within a short time after a dressing, showed several colonies of *Staphylococcus aureus*. This, too, was undoubtedly a temporary bacteriemia. Other blood cultures were uniformly negative.

CLASSIFICATION AS REGARDS BACTERIEMIA

In actual practice it is found that cases of infection can be of three kinds, as regards the presence of a bacteriemia:

1. In the first variety a focus of infection is present with well marked local signs and symptoms but without any clinical signs of a general blood infection. A bacteriemia is not present. The physical basis for this variety lies (*a*) in a primary and temporary bacteriemia; (*b*) in the

development of a fixation point, and (*c*) in the subsequent spontaneous disappearance of the bacteriemia.

2. In the second variety a well marked focus of infection is present with abundant local signs and symptoms and, in addition, there are clinical indications of a bacteriemia as evidenced by the general signs and symptoms and by the demonstration of living bacteria in the blood stream. The physical basis for this variety is the presence of an infected thrombus-embolus formation which serves to keep up a demonstrable bacteriemia by constantly feeding into the blood stream a comparatively small number of viable organisms. Commonly, after efficient surgical treatment, the bacteriemia eventually disappears and a recovery is made.

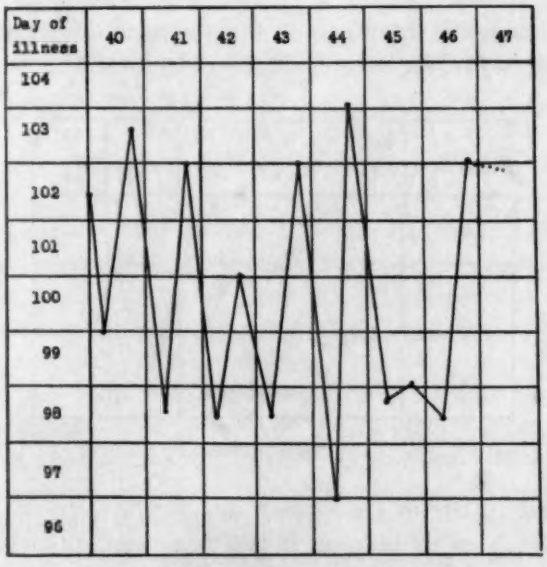

Fig. 8.—Temperature curve in Case 12.

It must be remembered that any of these cases may at any time pass into the third group. The possibility also exists, as mentioned in a preceding paragraph, of the local focus of infection in cases of this variety becoming a secondary point of distribution.

3. The clinical picture of the cases in this group is that of a profound general infection; there is a marked toxemia. A local focus of infection is either not demonstrable at all because of the paucity of local signs and symptoms, or because the latter are hidden in the profound intoxication, or, if present, the local lesion is easily recognized as being of no consequence in the total clinical picture. The physical basis of the picture lies in an extreme and severe general blood infection with highly virulent organisms in which the bacteria are rapidly multiplying in the

blood stream and because of which the subject is rapidly being overwhelmed by a tremendous intoxication. The presence of the infected thrombus-embolus formation forms a negligible factor and the few organisms that are derived from this source play only a primary and inciting part in the production of the bacteriemia; the subsequent multiplication in the blood stream depends on other factors, the most important of which lie in the high virulence of the infecting organism and in the poor resistance of the subject. An endocarditis is usually found under these conditions. In this variety the local point of fixation plays no rôle in the production of any part of the clinical picture. Usually the latter is not in an advanced stage at the time the lesion is exposed, either on the operating table, or, as more commonly happens, in the necropsy room.

In actual disease it seems certain that the cases differentiated in these three groups form progressive stages each from the next preceding

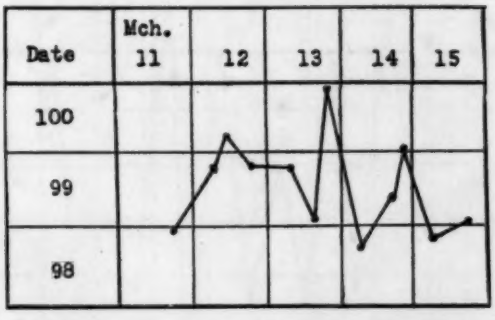

Fig. 9.—Temperature curve in Case 13.

group. A case in Group 1 may pass into Group 2; and, conversely, a case in Group 2, either because it had been appropriately treated, or spontaneously, may retrogress into Group 1 as it proceeds to healing and recovery. These interchanges are constantly occurring in clinical surgery. A case in Group 2 may pass into Group 3 as is previously noted; usually under such conditions there is a continued progression until the eventual fatality. In actual practice cases in Group 3 must necessarily first pass through the stage indicated by Group 2; the time interval may be so short, however, owing to the virulence of the infecting organism, as to be unrecognizable. One can explain the cases that apparently begin with the characteristics of the cases in Group 3 in this way. In many cases characteristics can be distinguished which belong to both Group 2 and Group 3; and so far as any case partakes of characteristics not belonging to its group, it differs in its clinical manifestations. I have never seen a case in Group 3 retrogress spontaneously into Group 2; it seems almost impossible to believe that such retrogression can ever occur.

From the facts stated here it becomes apparent that in any given case the presence of a bacteriemia must be referred: (1) to the primary lesion if this be present; (2) to any subsidiary lesion or to a number of them; (3) to the presence of a bacterial endocarditis, or (4) to a combination of these. In actual practice the relationship of the bacteriemia to the demonstrable lesions becomes an all important one and in certain cases valuable deductions can be drawn:

1. A single focus is apparently present in the presence of a bacteriemia in which comparatively small numbers of organisms are demonstrable in the peripheral blood. If, following an adequate operation in which the entire focus is removed, the bacteriemia disappears, it can properly be assumed that the bacteriemia resulted from that lesion. If, however, the bacteriemia persists after operation, and the surgeon is certain that the entire focus has been removed and the appearances of the resulting wound are healthy and corroborate this impression, the persistence of the bacteriemia may be used as evidence that some other focus exists which is causing the bacteriemia and which must be found and eradicated before the blood can become sterile and before cure can be affected. If, after a second focus is found and corrected, the bacteriemia still persists and the number of demonstrable organisms in the peripheral blood does not increase appreciably, indicating that the organisms are not multiplying in the circulation, a search for other foci must be made and a bacterial endocarditis must be excluded. The original focus should also be revised surgically. In the absence of these, the explanation of the bacteriemia becomes impossible for the moment even though it must necessarily be assumed that somewhere in the body an infected thrombus exists which is feeding bacteria into the circulation and which for the moment is not demonstrable. Prognoses under such conditions should always be made guardedly and with reservations, even though quite frequently eventual recovery ensues owing to the natural protective powers of the individual.

2. When several foci exist in the presence of a bacteriemia similar rules are followed and the explanation of the bacteriemia becomes a matter of exclusion.

3. In any case the relative numbers of bacteria demonstrable in the peripheral circulation in successive blood cultivations during the continued illness of the subject gives in appropriate cases valuable data for making prognoses: (*a*) Decreasing numbers of demonstrable organisms are associated with good prognosis. (*b*) Stationary numbers, when not too large, are associated with favorable prognoses, but with reservations. (*c*) When the numbers of bacteria are increasing, guarded prognoses should be given because the condition at the moment is a progressive one. (*d*) In the presence of large and overwhelming numbers of bacteria in

the peripheral blood, distinctly bad prognoses are indicated; usually the clinical picture is in accord with this. Increasing numbers of bacteria in the peripheral blood may diminish and disappear, especially if it is possible to eradicate completely the guilty foci. This is commonly seen in clinical practice. In the presence of bacterial multiplication in the blood stream, when large and overwhelming numbers are demonstrable in the peripheral blood, regression apparently is not possible.

4. In cases in which the bacteriemia continues in a comparatively unchanged condition in spite of all efforts, an endocarditis must be considered. The presence of a constant murmur—to be distinguished from anemic murmurs—should be taken as evidence that thrombi are present on the heart valves from which the bacteriemia is derived. The great majority of fatal cases of bacteriemia and general blood infection have this lesion at death among others.

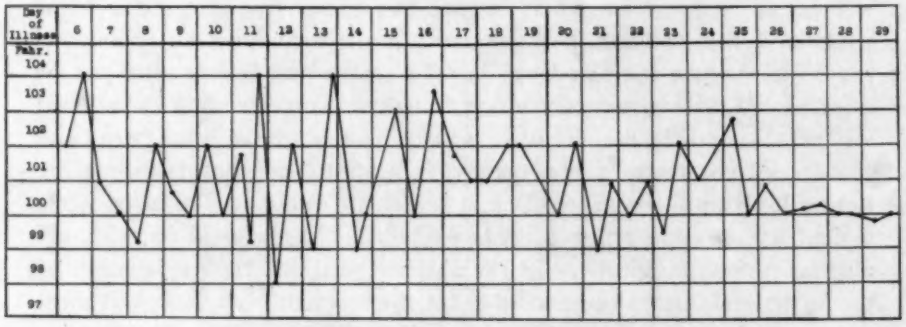

Fig. 10.—Temperature curve in Case 14.

CASE 14.—A young child was admitted to the hospital on the sixth day after the onset of an acute suppurative otitis media. The blood culture was sterile. There was apparently no mastoid involvement. On the fifteenth day, an arthritis of one ankle developed which was incised on the seventeenth day. On the twentieth day the blood cultivations showed one colony which on smear showed gram-positive cocci and a gram-negative bacillus. It was not possible for the pathologist, Dr. Gross, to identify these organisms. On the twenty-fourth day a focus developed in the left wrist and elbow, and on the twenty-fifth day the blood cultivation was sterile. The otologist, Dr. S. J. Kopetzky, suspected that a sinus thrombosis was present in association with the otitis media, but the physical signs and other evidence did not warrant any operative intervention. The child subsequently recovered.

This must have been a temporary bacteriemia of some sort. A good prognosis was always entertained and the impression proved correct.

I refer again to Case 2. In spite of the fact that the temperature and other constitutional symptoms continued during the time the bacteriemia was present, a guardedly favorable prognosis could be made. This was

possible because of the small number of bacteria in the circulation and because of the general condition of the patient.

CASE 15.—A young man developed an infection of the finger with high fever ten days before admission to the hospital. The temperature continued after the finger had been properly incised and two days later a carbuncle of the back of the thorax developed. Three days later the latter was incised. The temperature continued, however, and two days afterward the patient began to cough and brought up bloody sputum. On the day of admission, the eleventh of his illness, the physical examination showed a healing wound on the back and râles in both lungs, especially in their upper parts. The blood cultivation of the peripheral blood showed 190 colonies of *Staphylococcus aureus*. As shown in the chart, the number of colonies in the blood culture steadily declined until on the seventeenth day there were only 25 colonies per cubic centimeter of blood. Meanwhile the physical signs in the chest had increased until they were those of a confluent bronchopneumonia and the general condition of the patient remained fair.

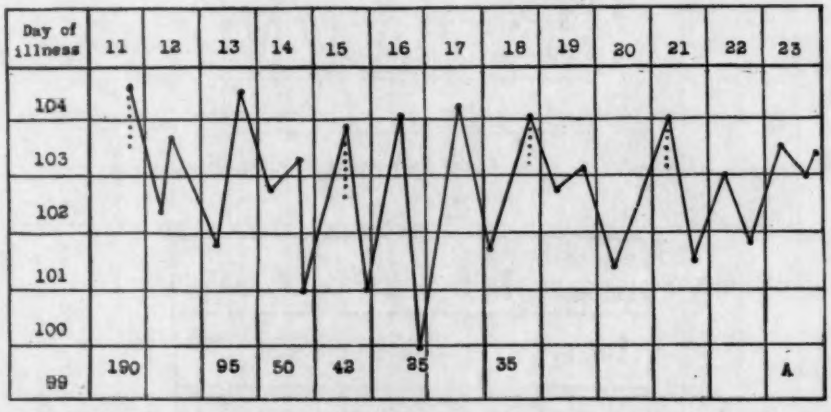

Fig. 11.—Temperature curve in Case 15; the figures represent the number of colonies of *Staphylococcus aureus; A,* numerous colonies.

During the last week of his illness the number of colonies again increased, the general condition deteriorated and the patient finally died.

During the first week the prognosis was certainly a most grave one but there seemed to be some hope from the continual improvement in the bacteriemia. The character of the physical signs and the general appearances of the patient contradicted this. In the last week all the available evidence seemed to indicate that a fatal issue would ensue.

CASE 16.—A patient was admitted to the hospital on the third day after he had been kicked in the knee. The admission temperature was 105 F. and the constitutional symptoms were those of a profound infection. An osteotomy was immediately done for an acute osteomyelitis. The bacteriologic studies showed *Staphylococcus aureus* in the pus from the bone and 25 colonies of the same organism in each cubic centimeter of blood. The after history suggested that the opening of the focus in the bone had no influence on the course of the illness, and death occurred four days later. Two days before death there were 150 colonies of *Staphylococcus aureus* per cubic centimeter of blood. The prognosis was bad from the time the patient was first seen.

Case 17.—A young woman developed a malignant pustule of the face with high temperature. *Bacillus anthracis* was found in smears taken from the wound and the blood culture showed innumerable colonies of anthrax bacilli. This was a hyperacute general blood infection from the start. A bad prognosis was immediately made.

Case 18.—A patient was admitted with a tonsillitis and high fever. The initial temperature subsided after the second day but returned the next day and steadily climbed to 105 F. Signs of a bronchopneumonia developed in one lung

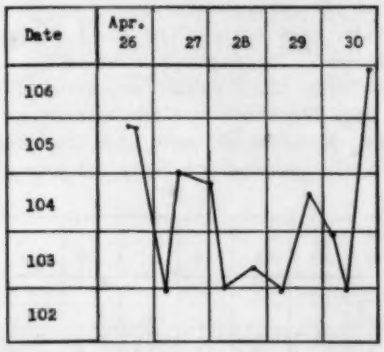

Fig. 12.—Temperature curve in Case 16.

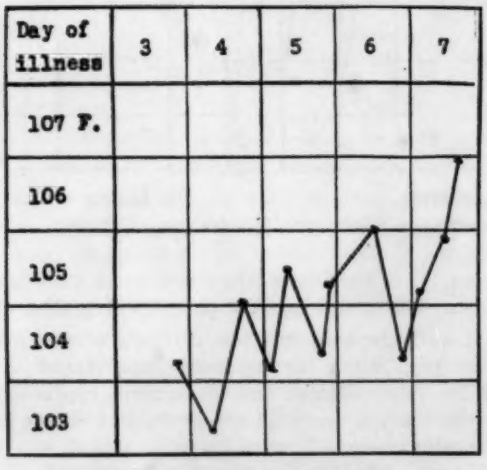

Fig. 13.—Temperature curve in Case 17.

and toward the end of the illness jaundice developed. The general appearances were those of a severe infection. A cultivation of the blood made on the seventh day of the illness and at the height of the temperature showed many colonies of a hemolytic streptococcus.

Case 19.—A patient developed abdominal symptoms shortly after an acute tonsillitis. There were pain and cramps, most marked in the left lower abdominal quadrant, with some nausea and vomiting and a temperature of 103 F. The physical examination showed objective signs of a spreading peritonitis arising

from the pelvis. The vaginal and rectal examinations gave no positive findings. Laparotomy showed a diffuse peritonitis and spreads of the exudate showed pneumococci. The course of the illness was a progressive one and the temperature is shown in Figure 16. The blood culture was positive. The patient died.

There is room for a difference of opinion as to whether the portal of entry for the infection was the tonsil or the genital tract. The prognosis was bad from the time the patient was first seen. The peritonitis was a secondary focus of the infection and it is not possible to say whether the bacteriemia was referable to the primary or to the secondary lesion. A general blood infection (multiplication of the organisms in the blood stream) was present before death.

CASE 20.—A young girl developed a focus of infection in the general region of the right groin with general constitutional symptoms indicating a profound

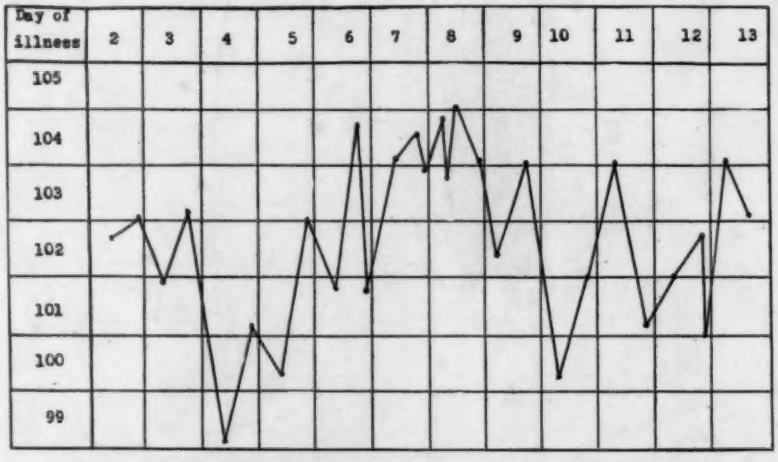

Fig. 14.—Temperature curve in Case 18.

infection. Operation showed that an infection had centered in the right hip joint, that the process had ruptured through the hip capsule, and that an abscess had formed outside the joint in the groin. Ample incision and drainage made no apparent effect on the signs and symptoms exhibited by the patient. The temperature curve up to the time of death is shown in Figure 17, and demonstrates the progressive nature of the disease. A cultivation of the peripheral blood made on the second day of the patient's stay in the hospital showed 20 colonies of nonhemolytic streptococci per cubic centimeter of blood. Five days later, two days after operation, there were fifty colonies of bacteria per cubic centimeter of blood; two days before death there were more than 100 colonies per cubic centimeter of blood. Pus from the joint and inguinal abscess showed nonhemolytic streptococci also. There was no postmortem examination.

It may be taken for granted that a focus of this kind is always a secondary one during the course of an infection. It was not possible, either from the history, the physical examination, or the subsequent

observation to determine the primary focus of the infection. This, too, was a progressively increasing infection and the patient was first seen in the stage in which a bacteriemia had already been established. The fact that the number of colonies demonstrated in the blood cultivations increased in the second blood examination gave great grounds for making

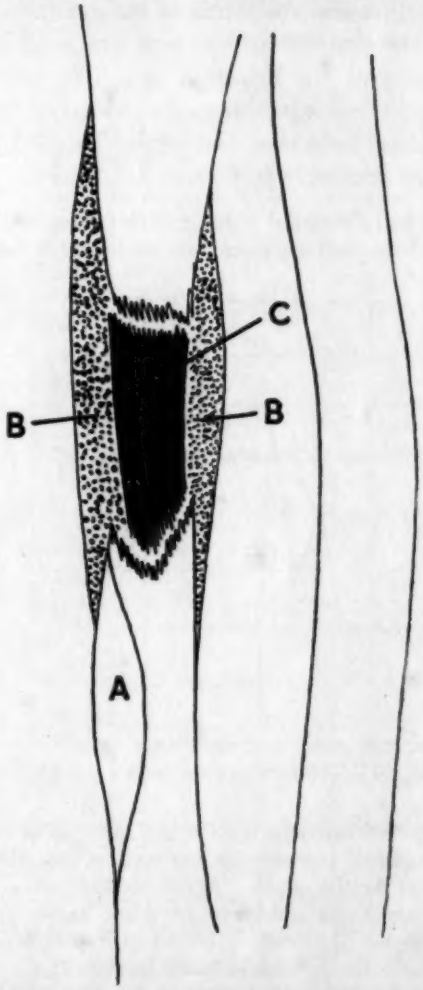

Fig. 15.—Sketch from roentgenogram in Case 19: *A*, primary osteotomy in radius; *C*, necrotic bone (sequestrum) which represents the spread of the focus at *A* by a spreading thrombosis, and *B*, involucrum around the sequestrum.

an unfavorable prognosis, and this was borne out by the clinical manifestations. There was a terminal general blood infection.

Case 21.—On the ninth day after a radical operation for carcinoma of the breast, the temperature and other clinical manifestations indicated that everything was going well. On the tenth day, there was a sudden rise in temperature, as

indicated in Figure 18. On the subsequent days the temperature was high, remittent and was marked by daily chills. There was edematous swelling of the upper flap of the wound, where it overlay the axillary vein and the arm became swollen in the next twenty-four hours. There was no retention, or other abnormality in the wound, and no other cause, by physical examination and by roentgen ray, to account for the symptoms. The physical characteristics of the wound and the swelling of the arm indicated that the diagnosis was a thrombosis of the axillary vein. Cultivations of the peripheral blood were sterile at this time.

SIGNIFICANCE OF CHILLS

In many of the cases cited it is to be noted that there is a succession of rises and falls in the temperature curve interpolated by numerous

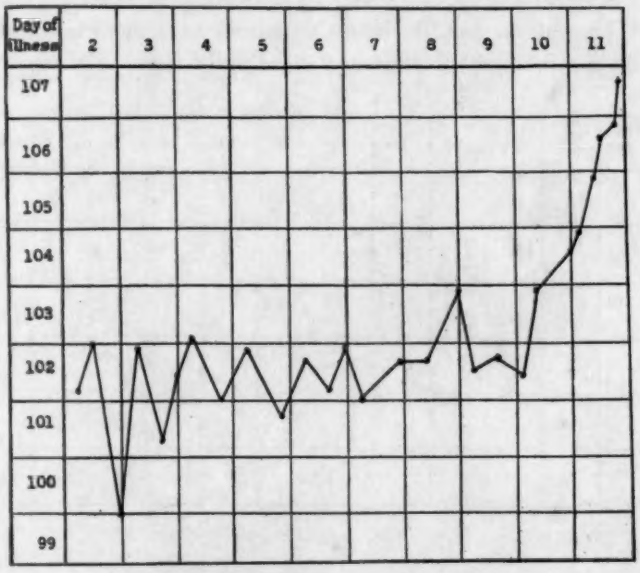

Fig. 16.—Temperature curve in Case 19.

chills. Such a temperature curve is always to be associated with bacterial thrombophlebitis in which the pathologic process is in an active stage and in which emboli are constantly being detached from the mother thrombus. Each of the chills and its subsequent rise of temperature corresponds to the breaking off of one or more parts of the thrombus and their discharge into the circulation as emboli, and with a sudden flooding of the circulation with organisms. The question whether these organisms are immediately destroyed completely or partially or are not interfered with at all, and whether the organisms so discharged into the circulation then proceed to multiply, is one that is intimately concerned with the bacteria destroying properties of the blood and, to an equal extent, with the virulence of the bacterial poisons set free in the

blood stream. The differentiation between bacteriemia and general blood infection, as previously defined in this article, and the occurrence of sterile blood cultures depends on the various relations of these all important general factors and the relative dominance of any one over any and all others.

The presence of chills in Case 21 indicated that this was not a quiescent thrombosis but an active one and that pieces of the thrombus had continued to be broken off at various times. The impossibility of demonstrating bacteria in the peripheral circulation indicated that the bacteria destroying powers of the blood were sufficient at this time to kill the bacteria as fast as they entered the circulation.

The question of prognosis was an important one at this stage of the illness. The general condition of the patient continued undisturbed and except for the fact that there were these daily rises of temperature and

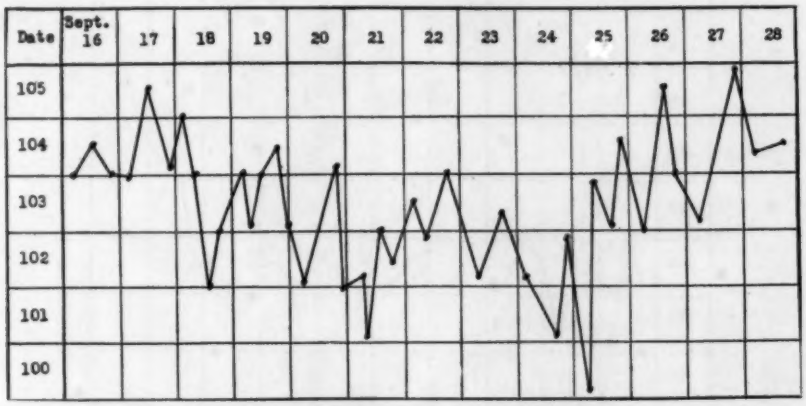

Fig. 17.—Temperature curve in Case 20.

repetitions of the chills, which incommoded the patient only while they lasted, there were no subjective or objective general manifestations indicative of the grave condition present. The condition of the wound continued as described. In clinical surgery such abnormalities of behavior occur after operation and usually these are only of temporary significance and disappear subsequently. The fact that a negative blood culture was obtained also was encouraging. A carefully guarded, favorable prognosis was, therefore, made at this time.

To continue the subsequent history:

During the fourteenth, fifteenth and sixteenth days after operation the daily level of the temperature showed a gradual decline. This was not coincident with any marked difference in the local conditions of the wound or in the general clinical manifestations. At this time we were much encouraged.

On the seventeenth day the temperature rose again and during the succeeding night and on the next day the chills were repeated. On the eighteenth day

the patient vomited for the first time. The general condition of the patient was still good. After continuing for two days the temperature again fell to 101.1 F. only to rise again to 104 F. on the same day. On the twenty-second day a subcutaneous abscess was discovered at one side of the scar and this was incised immediately. The incision and drainage, however, made no change in any of the clinical manifestations and from this time on, the temperature continued at a high level.

On the twenty-fifth day, there developed a persistent abdominal distention with nausea and continual vomiting of small amounts of bilious material. The bowels moved freely and the evacuations were of a diarrheal nature. The abdomen was soft in spite of its distention and was entirely free of pain, rigidity or tenderness. Nevertheless, I felt sure that a secondary lesion was going on in the abdominal cavity which I assumed was some form of a peritonitis.

A blood cultivation of the peripheral blood made on this day showed 26 colonies of hemolytic streptococci per cubic centimeter of blood. An abdominal

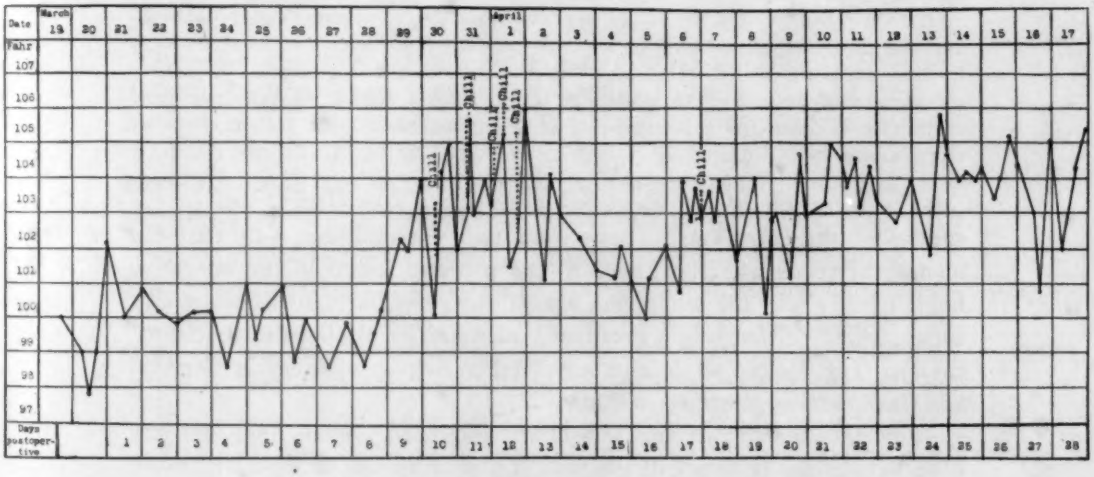

Fig. 18.—Temperature curve in Case 21.

aspiration was done and a few cubic centimeters of turbid fluid was obtained from the right flank. This was reported by Dr. Bernstein as containing no pus cells or bacteria on smear and as being bacteriologically sterile on culture. The patient's general condition began to deteriorate on this day.

The development of a secondary focus and the presence of a bacteriemia corroborated our assumption that a thrombophlebitis was present in one of the veins in the operated territory, most probably the axillary vein. The presence of the bacteriemia demonstrated that the resisting powers of the patient were flagging and that the organisms had established their position in the blood stream. From the relatively small number of organisms demonstrable, it was not possible to distinguish whether any multiplication of organisms was taking place in the circulation and whether enough natural protection still remained to keep the

number of organisms down to a low level. Probably some degree of multiplication must have taken place.

The laboratory data proved disturbing to the assumption that a peritonitis was present. The physical findings were suggestive and subsequently the continuance of the abdominal distention, of the nausea and of the frequent vomiting were seemingly not explainable except on that basis. At no time could we distinguish a pulmonary lesion to which abdominal distention might be a secondary manifestation, and on several days we could elicit the physical signs of ascites.

About this time the patient began to be drowsy. On the twenty-seventh day after operation the patient was deeply drowsy and could be aroused only with much effort. The general condition of the patient was poorer. There was increasing rigidity of the neck and a well developed Kernig's sign. In the evening the patient seemed stuporous.

On the twenty-eight day after operation all the symptoms had progressed and the diagnosis of meningitis seemed certain. This was corroborated by a lumbar puncture which released from the cerebrospinal space a few cubic centimeters of clear fluid in which Dr. D. J. Kaliski found 161 cells per cubic centimeter of which 88 per cent. were polymorphonuclear cells, and numbers of streptococci.

The infection of the meninges also was a secondary focus in the course of the infection. There were two possibilities: (1) that the meningeal focus was subsidiary to the primary lesion in the operative field; or (2) that the meningeal lesion was subsidiary to the secondary focus, whatever that might eventually prove to be, within the abdominal cavity. There were no data of any kind to help in making the decision and this question remained in doubt.

The development of this subsidiary focus, of course, removed any likelihood of the recovery of the patient and from this time on we looked for a fatality.

We resorted to several methods in the hope of removing the bacteriemia. A transfusion of blood was given to the patient. There was no time, of course, to give blood from an immunized donor. There was no apparent benefit following the transfusion. Full doses of gentian violet were given intravenously on several days. Except for a temporary fall in the temperature following the first of these, these injections also were followed by no apparent benefit. All of the signs and symptoms continued to increase progressively and on the twenty-ninth day after operation the patient died.

A postmortem examination of the body was made by Dr. Friedman. The notes of this are as follows:

The operative wound was in good condition. The axillary vein contained a thrombus in the region underlying the clavicle. This lay rather loosely in the lumen of the vein, was not obturating and was apparently unattached. The wall of the vein was apparently intact. There was a fresh bacterial endocarditis

with perforation of the valve cusps. There was an obturating thrombus in the terminal portion of the ileocolic artery. There was no peritonitis. There was no pneumonia.

This case is a most illuminating one and illustrates many of the points brought out in this article. The original point of entry for the infection was in the stump of one of the branches of the axillary vein in the operative field; because of some obscure factor, the thrombus which normally should occlude a ligatured vessel up to the point of junction with the next larger branch—in this case, the axillary vein—continued into the lumen of the latter; this made the mother thrombus. When this grew large enough, it presumably broke away from its point of attachment in the stump of the relatively small ligatured branch. Pieces of the mother thrombus breaking off and circulating through the vascular network of the body gave rise to the other lesions and foci detailed in the report of the case. Each accident of this kind, i. e., separation of one or of a shower of emboli, was marked clinically by a chill and a subsequent rise of temperature. As soon as bacteria began to grow on the surface of the various thrombi and emboli, bacteria began to appear in the circulating blood and were demonstrable in the cultivations of the peripheral blood. Later, the positive blood cultures were most probably due to the valvular lesion.

The presence of the abdominal distention, nausea and vomiting was finally explained by the presence of the embolic thrombus in the ileocolic artery. The interference with blood supply was undoubtedly much less than at the beginning; this corresponds with some diminution of the clinical symptoms referable to the abdomen in the terminal part of the illness.

Vascular thrombosis in a focus of infection acts as an important factor in delimiting the size of the lesion and in explaining its gradual or sudden enlargement. Thromboses that do not increase are associated with foci that remain stationary and undergo healing. Thromboses extending by contiguity along the vascular pathways are associated with lesions that increase in size. A similar spread of a focus of infection can also be secured by penetration of the bacteria along the lymphatic channels. Sudden increase of the thrombotic process, as, for instance, when a vascular bifurcation is reached or when a main nutrient vessel is reached explains the apparently sudden exacerbations that sometimes take place in foci of infection that are apparently doing well, and the sudden appearance of bacteriemia, or of general blood infection. In certain organs and tissues, notably bone, it explains the many obscure manifestations that are constantly being seen as regards the difference in the size of the initial focus and its immediate partial regression when collateral circulation is established, and of many

phenomena which are constantly occurring and which are difficult of explanation on other bases.

CASE 19.—The notes of this case illustrate how impossible it would be to explain the clinical phenomena except on the spread of the thrombo-embolic process. A young girl was operated on for a focus of osteomyelitis in one radius. A radical osteotomy was immediately done and thereafter the wound did well. At a subsequent dressing the appearances of the wound were those to enable one to strap the lips of the wound together with the expectation of an immediate agglutination; this occurred and about ten days later it appeared that the wound had practically healed. The patient returned several days later with a recrudescence in the arm and a roentgenogram (Fig. 5) showed something that appeared at first sight as a new focus close to the old one. This, however, was in reality a spreading of the original focus by retrograde thrombosis until a large trunk vessel had been reached in which the extension of the thrombosis and the spread of the infection had caused the involvement of another area of the same bone and the formation of a sequestrum.

Subsidiary foci of infection have often been termed fixation points on the supposition that, when such a secondary focus forms, it attracts to itself any bacteria that are present in the circulation and renders the latter sterile. This is true in the sense that the embolus that originates the subsidiary focus is the only part of the primary thrombus that carries the organisms from which the bacteriemia is derived, and that when the embolus is caught at its fixation point and properly blocked off by thromboses around itself no further discharge of bacteria can occur, at least temporarily. It is still possible for a bacteriemia or general blood infection to be derived from the primary thrombus at the original portal of entry of the infection or from others of its emboli that are being discharged either simultaneously or subsequently to the formation of the fixation point. In actual practice the bacteriemia does or does not disappear in accordance with the physical characteristics of the mechanism as here described.

This assumption is also true in the sense that sterile portions of a thrombus may form sterile emboli which, becoming caught at some point of the vascular network, form fixation points for the subsequent localization of any bacteria or bacterial emboli that may penetrate the circulation.

DISPOSAL OF BACTERIA ON RECOVERY

The ultimate fate of the bacteria in a case of infection from which recovery is made is a manifold one:

1. The organisms are taken up by the various protective cells, antibodies and fluids of the body until dissolution of them occurs.

2. Organisms are extruded and cast off from any operative or traumatic wound that is present.

3. Organisms that reach the liver disappear in their passage through the liver. In this regard it is known that certain classes of organisms are dissolved by bile.

4. Organisms are excreted from the intestinal tract, as in typhoid fever.

5. Organisms are excreted in the urine. In passing through and out of the urinary tract, the bacteria may leave no trace of their presence, or may cause surface infection of the lining epithelial membrane under proper conditions. The various other forms of nephritis or nephrosis that occur during an infection are due to the same thromboembolic phenomena previously described and to extension along the lymphatics of the kidney.

6. Small groups of organisms are isolated in the granulations of the healing wound and become encysted in the resulting scar tissue, or become encysted in organized thrombi. Sometimes as in typhoid bone infections they form sources from which subsequent secondary infections arise.

SODIUM CHLORIDE METABOLISM IN CUTANEOUS BURNS AND ITS POSSIBLE SIGNIFICANCE FOR A RATIONAL THERAPY*

EDWARD C. DAVIDSON, M.D.
DETROIT

The disturbance of fluid balance following extensive cutaneous burns is a well known phenomenon. Even though the fluid intake is relatively great during the first twenty-four hours, there is a marked urinary suppression. The normal ratio between fluid intake and output usually does not become established before the end of from forty-eight to seventy-two hours. During this period, the urine is deeply colored, has a high specific gravity, and may contain a trace of albumin. In view of this apparent suppression of the renal function and the fact that sodium chloride is badly tolerated by kidneys showing irritative lesions, it seemed desirable to study the sodium chloride metabolism and its relation to protein metabolism.

A number of observers have investigated the nitrogen metabolism in extensive burns. Robertson and Boyd [1] found that the nonprotein nitrogen of the blood was increased from 40 to 50 per cent in rabbits following burns. This was largely due to a relative increase of urea nitrogen, which constituted from 80 to 90 per cent of the total nonprotein nitrogen as is usually the case in rapid nitrogen retention. They attributed this rise to increased protein catabolism. Underhill and his associates [2] observed a similar elevation of the blood nonprotein nitrogen and urea nitrogen, but thought it due to blood concentration. Davidson [3] reported a suggestive parallelism between the blood nonprotein nitrogen and the clinical condition of the patient.

The chlorides of the blood in the normal person are relatively constant. Gettler and Baker [4] state that the normal whole blood chlorides vary from 450 to 500 mg., while the plasma chlorides, calculated as sodium chloride, vary from 560 to 640 mg. per hundred cubic centi-

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* From the surgical service of the Henry Ford Hospital.

1. Robertson, B., and Boyd, G. L.: Toxemia of Severe Superficial Burns, J. Lab. & Clin. Med. **9**:1-14 (Oct.) 1923.

2. Underhill, F. P.; Carrington, G. L.; Kapsinow, R., and Pack, G. T.: Blood Concentration Changes in Extensive Superficial Burns and Their Significance for Systemic Treatment, Arch. Int. Med. **32**:31-49 (July) 1923.

3. Davidson, E. C.: Tannic Acid in the Treatment of Burns, Surg. Gynec. Obst. **41**:202-221 (Aug.) 1925.

4. Gettler, A. O., and Baker, W.: Chemical and Physical Analysis of Blood in Thirty Normal Cases, J. Biol. Chem. **25**:211-222 (June) 1916.

meters. McLean and Van Slyke [5] place the normal chlorides of whole blood at 490 mg. per hundred cubic centimeters and the normal plasma chlorides at from 597 to 614 mg.

The only recorded blood chloride observations in burned persons are those by Underhill [2] made in conjunction with studies on blood concentration. He did not record any urine examinations and the blood chlorides were determined for a maximum of three days. In a number of cases only one specimen of blood was analyzed. A lowering of blood chlorides was observed and was explained on the basis of blood concentration in response to the local inflammatory reaction and the pouring out of plasma on the skin surface. He concluded that in the rapid interchange of fluid during the inflammatory stage of burns the sodium chloride functioned prominently.

METHOD

Patients were placed on a diet [6] that consisted of approximately 60 Gm. of protein with sufficient fat and carbohydrate to give a total caloric value of about 2,500 calories. The sodium chloride content of the diet was approximately 9 Gm. The amount refused was weighed and the total ingested food calculated. Fluids were forced energetically. The twenty-four hour intake of fluid was measured and the total urine collected. Periods ended at 7 a. m. when the patient was requested to void so that the division into day periods would be as accurate as possible. A specimen of blood was taken at this time. Heparin was generally used as the anticoagulant but occasionally sodium oxalate was employed.

The whole blood chloride values were determined in all instances by the Whitehorn method.[7] In the case detailed in table 3, the whole blood chlorides and plasma chlorides were determined by both the Whitehorn and Van Slyke [8] methods, to ascertain whether chloride could be bound with protein. The blood was collected and centrifugalized under oil and the analysis was done immediately to prevent any appreciable change in the plasma chlorides [9] due to a shift of chlorides between plasma and corpuscles. Plasma volumes were determined by centrifugalizing the whole blood for twenty minutes at 2,500 revolutions per

5. McLean, F. C., and Van Slyke, D. D.: A Method for the Determination of Chlorides in Small Amounts of Body Fluids, J. Biol. Chem. **21**:361-370, 1915.

6. Locke, E. A.: Food Values, New York, D. Appleton & Co., 1920.

7. Whitehorn, J. C.: System of Blood Analysis, J. Biol. Chem. **45**:449-460 (Feb.) 1921.

8. Van Slyke, D. D.: The Determination of Chlorides in Blood and Tissues, J. Biol. Chem. **58**:523-529 (Dec.) 1923.

9. McLean, F. C.: The Numerical Laws Governing the Rate of Excretion of Urea and Chlorides in Man, I, An Index of Urea Excretion and the Normal Excretion of Urea and Chlorides, J. Exper. Med. **22**:212-216, 1915.

minute. The nonprotein nitrogen was determined by the method of Folin and Wu [10] and the carbon dioxide combining power by the method of Van Slyke.[11] For the total nitrogen in the urine Folin's method was used, and for the chlorides the Whitehorn method.

RESULTS: MINOR BURNS

No alterations were found in either the blood or the urine chlorides in a group of seven cases of minor burns in which the lesions were not extensive and little tissue was actually devitalized, but in which the thermal agent was of sufficient intensity to cause a marked local edema. In table 1 are shown the results in a person who was burned to the first degree over the entire face and neck. There were a few small blebs over this area and the dorsum of each hand revealed a second degree burn. In this instance there was a normal chloride output in the urine and neither the whole blood nor the plasma chlorides revealed any striking change.

TABLE 1.—*Blood and Urinary Chlorides in Patient (Case 1) with First Degree Burn of Face and Second Degree Burn of Hands*

	Fluids		Diet		Blood				
Date	Intake, Cc.	Output, Cc.	Calories	Sodium Chloride, Gm.	Sodium Chloride Whole Blood 100 Cc., Mg.	Sodium Chloride Plasma 100 Cc., Mg.	Red Blood Cells, per Cmm.	Hemoglobin, per Cent	Urine: Sodium Chloride, Gm.
8/30	5,400	.....	2,598	5.5	450	624	4,970,000	116	2.4
8/31	5,550	1,580	2,656	8.2	470	...	4,920,000	108	10.5
9/ 1	2,804	2,980	2,601	9.00	462	619	.....	104	8.60
9/ 2	4,290	2,920	2,487	7.1	462	599	4,080,000	94	9.64
9/ 3	5,660	3,420	2,633	8.4	462	586	.....	...	10.44
9/ 4	3,920	2,460	2,341	6.7	462	569	4,250,000	90	6.09

MODERATE BURNS

A group of twelve patients with burns of somewhat greater extent and severity were observed showing second or third degree burns that involved a cutaneous area of somewhat less than 1,000 sq. cm. In general there was a transient but definite disturbance of chloride metabolism. The values for the blood chlorides fell but promptly returned to normal, while the urine revealed a mild, temporary chloride suppression. In figure 1 are shown the curves of the whole blood chlorides of the individual cases as well as the average curve for the group. An initial fall is noted with a secondary rise to normal limits, the latter taking place on about the fifth or sixth day.

10. Folin, O.: Laboratory Manual of Biological Chemistry, New York, D. Appleton & Co., 1922.

11. Van Slyke, D. D.: A Method for the Determination of Carbon Dioxide and Carbonates in Solution, J. Biol. Chem. **30**:347-368 (June) 1917.

TABLE 2.—*Blood and Urinary Chlorides in Patient (Case 5) with Second Degree Burn of Left Leg*

	Fluids		Diet			Urine		Blood						
Date	Intake, Cc.	Output, Cc.	Calories	Nitrogen, Gm.	Sodium Chloride, Gm.	Nitrogen, Gm.	Sodium Chloride, Gm.	Non-protein Nitrogen per 100 Cc., Mg.	Sodium Chloride Whole Blood per 100 Cc., Mg.	Sodium Chloride Plasma per 100 Cc., Mg.	Carbon Dioxide Combining Power, per Cent by Volume	Plasma Volume, per Cent	Hemoglobin, per Cent	Red Blood Cells, per Cmm.
8/18/25	5,100	5,050	.....	...	...	2.2	0.54	33.3	360	...	....	....	86	4,250,000
8/19/25	5,025	4,000	989	3.4	2.1	28.0	2.3	37.0	379	553	58.7	56.4	87	4,270,000
8/20/25	5,725	2,750	1,926	6.8	7.0	19.4	1.6	40.0	421	528	51.4	56.0	..	.....
8/21/25	4,360	1,800	2,460	9.4	8.3	23.3	0.7	26.0	478	619	55.3	52.9	..	4,020,000
8/22/25	3,005	1,800	2,188	9.1	9.6	....	....	38.5	437	...	53.7	57.0	..	3,650,000

In table 2 are shown the results in a case of second degree burn of the left leg below the knee. In this instance there was a striking fall of both the whole blood and the plasma chlorides. There was a slight diminution of urine chlorides and a markedly increased output of nitrogen in the urine. Plasma volume and blood counts revealed no evidence of blood concentration. The carbon dioxide combining power remained practically unchanged.

EXTENSIVE BURNS

Observation was made of a group of twelve subjects with extensive burns in whom the lesions were of second or third degree and involved

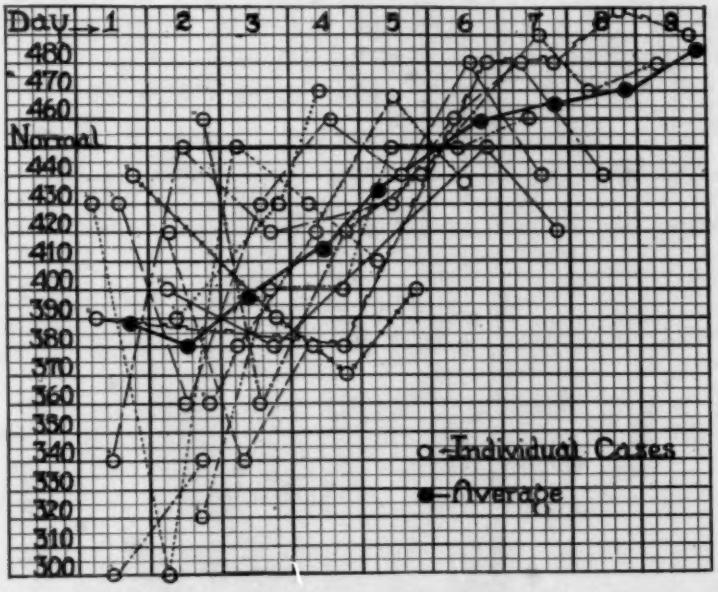

Fig. 1.—Whole blood chlorides following moderate burns.

a cutaneous area varying in size from about 1,000 sq. cm. to a maximum of 24 per cent of the total body surface. Figure 2 shows the whole blood chloride curves of the individual cases as well as the average curve for the group. A fall was noted similar to that seen in less extensive burns. However, this persisted during the entire time that the tissue devitalized by the burn was present. On its separation, elevation to normal limits occurred. It will be observed that the average whole blood chloride curve for the group did not approach normal until after the seventeenth day.

Table 3 summarizes the results in a third degree burn extending from the right ankle to the buttocks. The anterior aspect of the right

TABLE 3.—*Blood and Urinary Chlorides in Patient (Case 13) with Third Degree Burn of Right Leg*

Date	Maximum Temperature (Mouth) F.	Fluids		Diet			Blood								Urine	
		Intake, Cc.	Output, Cc.	Calories	Nitrogen, Gm.	Sodium Chloride, Gm.	Plasma Volume, per Cent	Carbon Dioxide Capacity, per Cent by Volume	Plasma Sodium Chloride per 100 Cc. (Van Slyke), Mg.	Plasma Sodium Chloride per 100 Cc. (Whitehorn), Mg.	Whole Blood Sodium Chloride per 100 Cc. (Van Slyke), Mg.	Whole Blood Sodium Chloride per 100 Cc. (Whitehorn), Mg.	Non-protein Nitrogen per 100 Cc., Mg.	Hemoglobin, per Cent	Red Blood Cells, per Cmm.	Total Nitrogen, Gm.	Total Sodium Chloride, Gm.
10/20/25	102	3,540	1,550	144	0.1	0.01	39.1	51.1	585	595	426	425	36.8	...	.....	11.21	3.91
10/21/25	99.8	4,130	1,575	896	1.8	0.61	34.2	54.8	563	543	385	416	48.2	...	.....	8.55	0.026
10/22/25	101	3,680	1,930	743	2.3	0.58	42.7	57.0	523	519	374	377	60.8	123	6,450,000	11.35	Trace
10/23/25	100.5	4,500	3,250	681	1.6	0.37	46.3	62.3	510	444	338	357	44.4	111	5,440,000	21.7	0.054
10/24/25	100.5	3,150	3,290	669	1.3	0.60	46.4	60.0	475	...	362	377	58.8	106	6,400,000	21.4	Trace
10/25/25	101.2	3,440	2,950	845	2.1	0.45	51.7	54.3	475	469	352	367	51.2	100	4,600.000	22.0	0.049
10/26/25	100.5	2,460	1,700	707	1.5	0.63	50.0	49.7	465	478	329	368	55.0	93	5,400,000	11.32	Trace
10/27/25	100.6	2,960	2,190	926	3.7	3.90	52.0	44.6	490	487	...	380	40.0	78	4,500,000	16.42	Trace
10/28/25	100.2	4,250	2,740	959	4.1	3.83	49.7	57.7	445	472	332	354	35.1	...	.....	9.44	Trace
10/29/25	100.6	3,810	3,330	833	2.7	6.73	54.8	50.2	519	468	358	340	43.2	78	.....	8.0	0.083
10/30/25	100	2,810	2,850	811	2.4	6.87	49.3	63.4	498	442	376	379	50.0	87	4,600,000	13.4	Trace
10/31/25	100.2	5,000	3,970	1,142	4.4	8.17	58.8	34.5	489	442	384	350	31.5	...	.....	12.4	0.328
11/ 1/25	100.4	7,460	4,390	1,841	5.6	7.76	54.0	46.4	561	512	407	380	41.0	...	.....	10.67	0.435
11/ 2/25	100	7,700	4,350	2,165	8.5	11.7	59.1	55.7	524	506	435	424	33.8	...	.....	14.48	1.88
11/ 3/25	99.6	6,960	5,000	2,066	7.8	9.6	61.9	55.5	550	525	454	456	25.9	76	3,850,000	11.80	5.65
11/ 4/25	100	6,860	6,050	2,375	8.4	11.4	61.5	59.0	559	565	478	480	31.0	72	3,530,000	8.17	6.66
11/ 5/25	99	8,850	7,750	1,836	8.6	11.9	64.2	59.3	547	541	467	475	29.9	70	3,560,000	12.40	14.24
11/ 6/25	99	3,670	5,290	2,494	9.3	11.6	61.3	55.1	582	610	488	504	38.6	70	3,010,000	9.49	10.88
11/ 7/25	99.1	8,400	8,285	2,747	10.1	10.5	62.3	....	570	552	465	464	42.6	69	3,530,000	12.10	15.36
11/ 8/25	99	9,260	5,750	1,226	10.0	12.4	63.1	60.0	572	552	482	465	46.2	...	.....	8.77	9.28
11/ 9/25	100.2	8,305	5,950	2,777	9.4	6.97	60.0	62.9	574	545	466	...	51.2	67	3,500,000	10.30	10.95
11/10/25	100.4	7,925	8,710	2,743	10.4	6.87	61.9	53.3	565	...	475	461	41.9	63	3,570,000	10.45	12.65
11/11/25	100	6,965	5,840	2,375	10.0	6.87	....	....	...	...	...	...	....	...	.....	7.96	10.42
11/12/25	99.2	5,900	8,200	2,400	9.4	7.46	....	....	...	...	...	...	....	72	3,780,000	8.39	7.50
11/13/25	100	7,340	7,430	2,743	9.4	8.80	....	....	...	...	...	...	....	74	3,840,000	7.43	6.58
11/14/25	100	7,760	7,600	.....	....	....	....	....	...	...	...	...	....	70	3,700,000	8.47	7.65

thigh revealed a second degree burn. During the early period of observation the diet was inadequate because of the patient's refusal to eat.

The hemoglobin determinations, red blood cell counts and plasma volume observations reveal a striking blood concentration during the first five days, after which blood dilution took place gradually, and a moderate anemia developed. The plasma volume reached a maximum of 64.2 per cent by volume, the red blood cell count fell to 3,010,000 per cubic millimeter, and the hemoglobin dropped to 69 per cent.

The whole blood and plasma chlorides showed a gradual fall during the first nine days and then returned slowly to normal. During this time there was no true relationship between the plasma volume and the

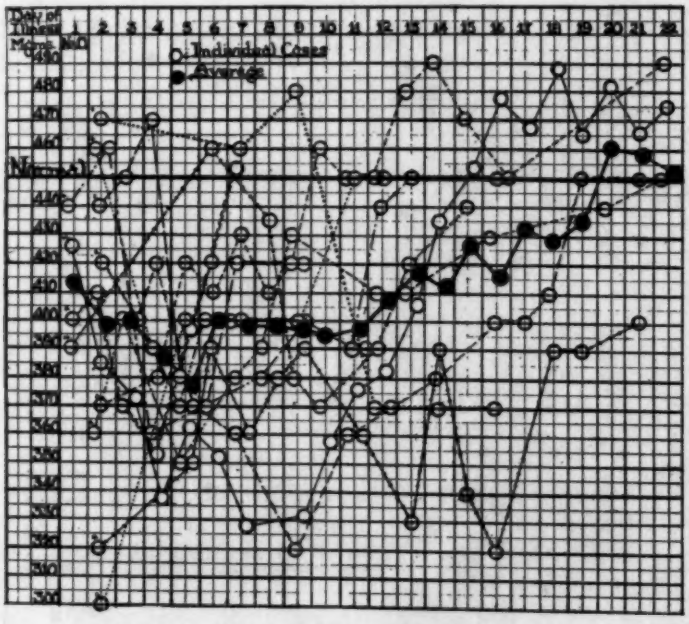

Fig. 2.—Whole blood chlorides following extensive burns.

chloride values (figs. 3 and 4). During the first two days, when the blood was most concentrated as evidenced by the low plasma volume, the plasma and whole blood chlorides were just beginning to fall and did not reach the low point until the tenth day when the plasma volume had returned to normal. The urinary chlorides were strikingly diminished and this diminution is seen to bear a direct relationship to the lowered plasma chlorides (fig. 5). In convalescence, when most of the sloughs had separated, there was a sudden outpouring of chlorides in the urine (fig. 6) quite similar to that seen following the crisis in pneumonia. After this time there was a fairly normal ratio between the salt intake and the chloride output.

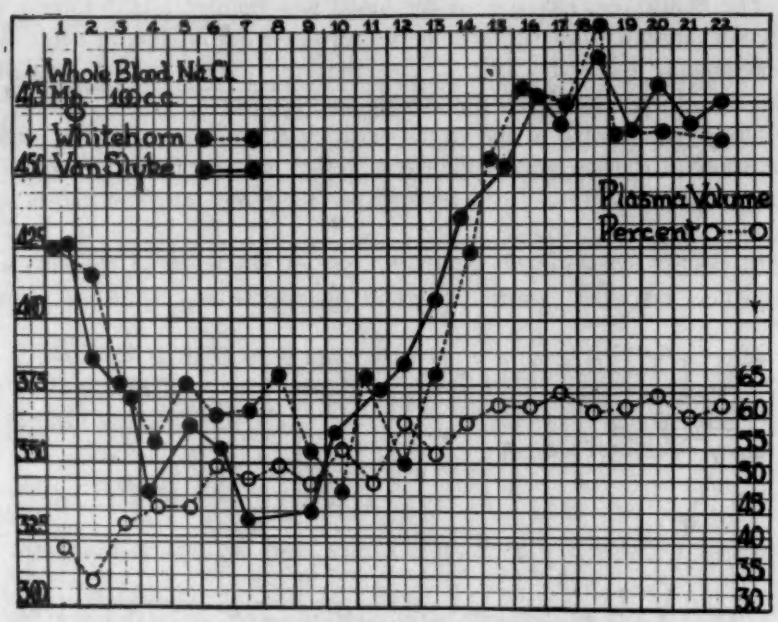

Fig. 3 (case 13).—Whole blood chlorides in relation to plasma percentage by volume.

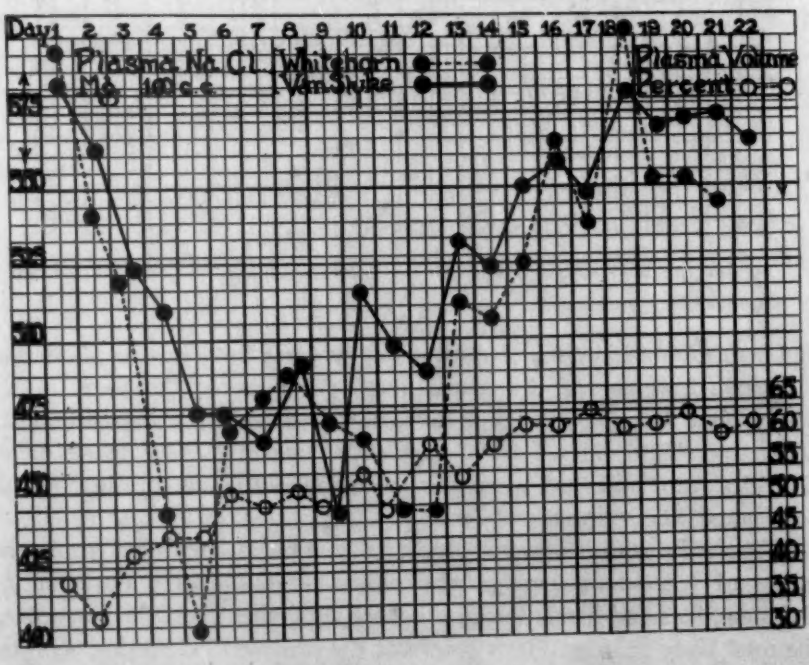

Fig. 4 (case 13).—Plasma chlorides in relation to plasma percentage by volume.

The nonprotein nitrogen of the blood was relatively high during the first ten days of observation and the nitrogen output in the urine was tremendously increased (fig. 6), so that the patient was in negative balance until practically all the sloughs had separated.

During the entire period of observation there was no characteristic alteration in the carbon dioxide combining power of the plasma. In spite of the marked metabolic disturbance the temperature elevation was not high.

In table 4 are summarized the results of whole blood chloride and nonprotein nitrogen determinations in relation to red blood cell counts

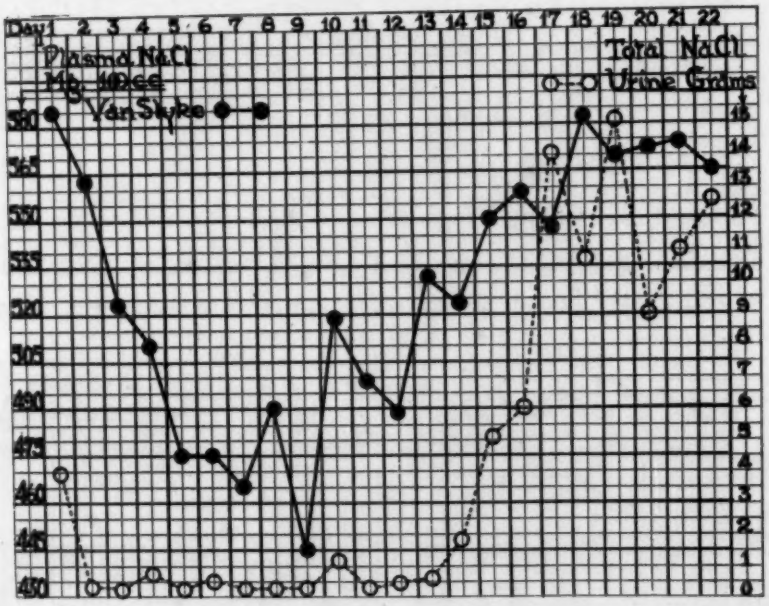

Fig. 5 (case 13).—Plasma and urinary chlorides during period of three weeks following burn.

and hemoglobin contents. In this group of cases there has been observed a definite lowering of the whole blood chlorides. Alterations of the hemoglobin and red cell count have not paralleled the changes in the whole blood chlorides. In a number of instances low whole blood chlorides were observed when the red blood cell count and hemoglobin percentage were normal or below.

Figure 7 shows the relationship of whole blood chlorides to temperature and pulse in a person who had a second degree burn of the abdomen, legs and hands which involved altogether about 18 per cent of the total body surface. It is seen that the low blood chlorides persisted after the temperature had reached normal.

TABLE 4.—*Blood Chlorides and Nonprotein Nitrogen in Relation to the Hemoglobin Percentage and Red Blood Cell Counts*

Case	Date	Whole Blood Sodium Chloride per 100 Cc., Mg.	Nonprotein Nitrogen per 100 Cc. Mg.	Red Blood Cells, per Cmm.	Hemoglobin, per Cent
2	1/29/25	420	37.0	.....	...
	1/30/25	340	45.0	5,000,000	96
3	1/29/25	300	35.3	.....	...
	1/30/25	340	30.0	4,580,000	94
4	1/21/25	500	31.6	4,300,000	80
	1/22/25	400	31.9	4,370,000	81
	1/28/25	450	33.0	4,510,000	90
5	8/18/25	360	33.3	4,250,000	86
	8/19/25	379	37.0	4,270,000	87
	8/20/25	421	40.0	4,020,000	78
	8/21/25	478	26.0	3,650,000	78
6	8/15/25	460	30.9	4,360,000	78
	8/16/25	430	31.2	.....	...
	8/17/25	390	25.9	3,520,000	82
	9/18/25	370	28.5	3,890,000	75
	8/19/25	400	28.0	3,920,000	80
7	7/29/25	460	28.2	.....	...
	7/30/25	360	30.0	3,990,000	82
	7/31/25	420	30.0	4,240,000	83
	8/ 1/25	440	33.0	3,920,000	80
	8/ 3/25	490	26.1	4,000,000	85
8	1/21/25	440	32.3	4,530,000	90
	1/22/25	460	30.9	4,490,000	88
	1/24/25	360	31.2	4,620,000	90
	1/28/25	380	34.1	4,320,000	80
9	3/11/25	300	39.5	4,820,000	88
	3/12/25	430	46.0	.....	...
	3/13/25	...	26.1	4,580,000	90
10	11/10/24	...	38.0	4,650,000	90
	11/11/24	370	40.6	4,000,000	98
	11/13/24	380	34.1	.....	...
	11/14/24	420	....	3,500,000	74
	11/18/24	420	33.0	3,750,000	72
11	8/22/25	320	25.9	.....	...
	8/25/25	350	25.0	3,840,000	77
	8/26/25	390	30.0	4,540,000	72
	8/28/25	380	32.3	3,540,000	73
	8/29/25	390	26.1	3,790,000	68
	9/ 2/25	330	26.8	3,880,000	70
	9/11/25	400	24.2	3,050,000	60
	9/17/25	450	27.5	3,750,000	67
12	7/28/25	400	33.0	4,720,000	105
	7/29/25	410	28.9	4,890,000	98
	7/30/25	370	27.0	4,340,000	...
	7/31/25	354	30.5	4,220,000	93
	8/ 1/25	396	33.5	4,420,000	90
	8/ 2/25	421	40.0	4,360,000	84
	8/ 9/25	454	40.0	4,480,000	90
13	10/20/25	426	36.8	.....	...
	10/21/25	385	48.2	.....	...
	10/22/25	374	60.8	6,450,000	123
	10/23/25	338	44.4	5,440,000	111
	10/24/25	362	58.8	5,400,000	106
	10/25/25	352	51.2	4,600,000	100
	10/26/25	329	55.0	5,400,000	93
	10/27/25	...	40.0	4,500,000	78
	10/29/25	358	43.2	.....	78
	10/30/25	376	50.0	4,600,000	...
	11/ 4/25	454	25.9	3,850,000	76
	11/ 5/25	478	31.0	3,580,000	72

COMMENT

The observations here reported reveal a striking alteration of chloride metabolism in cutaneous burns. To explain this phenomenon, diet, body temperature, loss of chlorides through vomiting, alkali therapy, altered renal threshold, concentration of blood, and finally transudation of plasma at the site of the burn must be considered.

Mayer [12] reduced the sodium chloride of his diet to 1.25 Gm. per day and after weeks of observation did not notice any deleterious effect. Austin and Jonas [13] concluded from a series of feeding experiments in dogs that the plasma chlorides could not be elevated or lowered by alterations in chloride intake except in a very transient manner. Underhill and Wakeman [14] found that the concentration of chlorides in the blood remains practically constant during fasting. In the cases presented, approximately from 7 to 9 Gm. of sodium chloride was given daily. Nevertheless, marked changes were found in the blood chlorides. In case 13 there was a low chloride intake during the early period of observation due to the patient's refusing to take his diet. This would in part account for the practical absence of sodium chloride in the urine during this period. However, even after he began to ingest sodium chloride an appreciable amount did not appear for a number of days. When the devitalized tissue at the site of the burn separated, there was an outpouring of sodium chloride in the urine which was greater than that provided by the diet (table 3 and fig. 6). These facts suggest that storage of sodium chloride takes place.

The exact importance of fever in relation to chloride metabolism is not clear, as pointed out by Peabody.[15] McLean [16] found that in fever the average renal threshold for chlorides was 542 mg. per hundred cubic centimeters of plasma instead of the normal value, 562 mg. Practically all patients with extensive burns are febrile during convalescence. However, in this series one patient (case 14) revealed a persistently low whole blood chloride after the temperature had become normal (fig. 7).

12. Mayer, A.: Observations sur l'urine de l'homme sain soumis à une alimentation pauvre en chlorure de sodium, Compt. rend. Soc. de biol. **58**:377, 1905.

13. Austin, J. H., and Jonas, L.: Effect of Diet on the Plasma Chlorides and Chloride Excretion in Dogs, J. Biol. Chem. **33**:91-101 (Jan.) 1918.

14. Underhill, F. P., and Wakeman, E. T.: The Behavior of Chlorides Introduced into the Blood Under Normal and Nephritic Conditions, J. Biol. Chem. **54**: 701-715 (Dec.) 1922.

15. Peabody, F. W.: Studies of the Inorganic Metabolism in Pneumonia with Especial Reference to Calcium and Magnesium, J. Exper. Med. **17**:71-82, 1913.

16. McLean, F. C.: The Numerical Laws Governing the Rate of Excretion of Urea and Chlorides in Man, II, The Influence of Pathological Conditions and Drugs on Excretion, J. Exper. Med. **22**:366-388, 1915.

It should further be noted that in case 13 (table 3) the whole blood and plasma chlorides, after falling to a low level, returned to normal limits while the temperature was still elevated. Accordingly, temperature per se could not explain this metabolic disturbance.

Lowering of the blood chlorides is observed when the normal passage of hydrochloric acid from the stomach to the intestines is interrupted. This loss of chlorides has been assumed by some to explain the low blood chlorides observed in pyloric stenosis,[17] pernicious vomiting of pregnancy,[18] and intestinal obstruction. Haden and Orr,[19] however, have

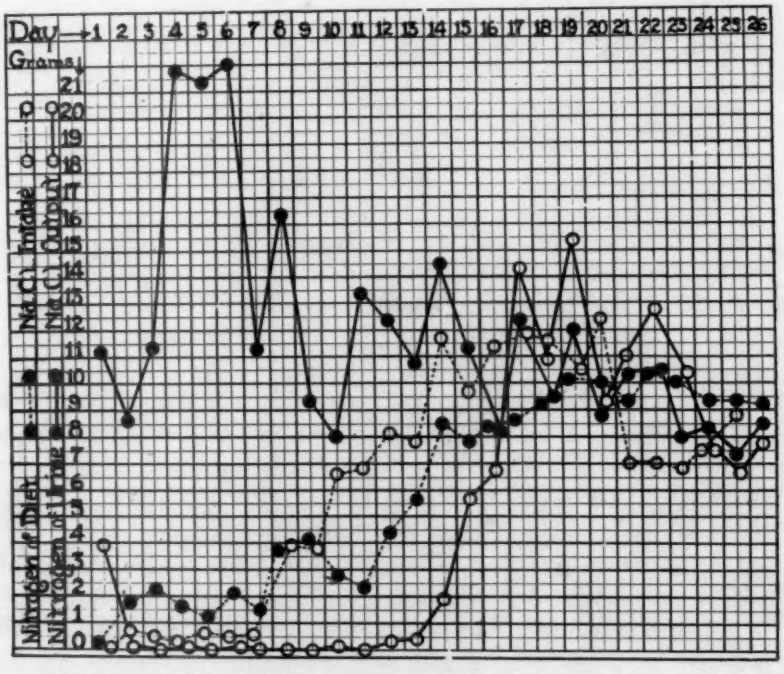

Fig. 6 (case 13).—Nitrogen and sodium chloride of diet and urine.

shown that the same fall in blood chlorides occurs in rabbits with intestinal obstruction although rabbits cannot vomit. They have further shown by analysis of the vomitus [20] that the chloride content is not suffi-

17. MacCallum, W. G.; Lintz, J.; Vermilye, H. N.; Liggett, T. H., and Boas, E.: The Effect of Pyloric Obstruction in Relation to Gastric Tetany, Bull. Johns Hopkins Hosp. **31**:1-7 (Jan.) 1920. Murray, H. A.: The Chemical Pathology of Pyloric Occlusion in Relation to Tetany, Arch. Surg. **7**:166-196 (July) 1923.

18. De Wesselow, O. L. V.: The Variations in the Chloride Content of the Blood, Internat. Clin. **3**:191-199, 1924.

19. Haden, R. L., and Orr, T. G.: Chemical Changes in the Blood of the Dog After Intestinal Obstruction, J. Exper. Med. **37**:365-375 (March) 1923.

20. Haden, R. L., and Orr, T. G.: Chemical Changes in the Blood of the Dog After Pyloric Obstruction, J. Exper. Med. **37**:377-381 (March) 1923.

cient to make up the deficiency observed in the blood. In this group of cases, vomiting was not a contributing factor to the lowering of the blood chlorides for in only one case did this occur and then on two occasions only.

Von Noorden [21] has mentioned the possibility of depleting the body of sodium chloride by the administration of large quantities of alkaline carbonates. This may explain the observation of Haden and Orr [22] that dogs with intestinal obstruction were in worse physical condition when given sodium bicarbonate than untreated animals were. Alkalis were not administered in any of the cases under discussion and so could not

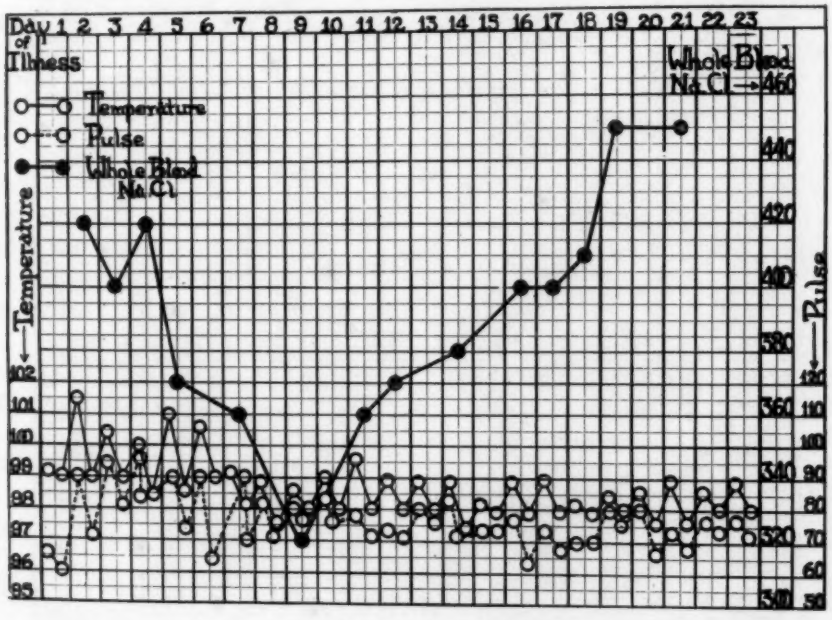
Day of Illness
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Temperature
Pulse
Whole Blood NaCl
Whole Blood NaCl
Temperature
Pulse

Fig. 7 (case 14).—Whole blood chlorides in relation to temperature and pulse.

possibly be a contributing factor. In those cases in which the carbon dioxide combining power of the plasma was determined, there was no striking elevation at the time the blood chlorides were at a low level.

Another possible explanation of the low whole blood and plasma chlorides is a lowering of the renal threshold with resulting blood depletion. In McLean's [16] exhaustive investigation of this problem he found that the threshold in diabetes mellitus averaged 512 mg. per hundred

21. Von Noorden, C.: Metabolism and Practical Medicine, London, William Heinemann, 1907, **1**:418.

22. Haden, R. L., and Orr, T. G.: The Effect of Sodium Chloride on the Chemical Changes in the Blood of the Dog After Pyloric and Intestinal Obstruction, J. Exper. Med. **38**:55-71 (July) 1923.

cubic centimeters of plasma instead of the value 562 mg. found in normal individuals. He further observed that certain diuretics caused a lower threshold, which resulted in chloride depletion of the plasma to a point lower than the lowest value seen in normal persons. Were this the cause of the low whole blood and plasma chlorides in burned patients, examination of the urine would show an increased chloride output. In case 13 there was practically a complete suppression of urinary chlorides (table 3 and fig. 5). Therefore, alteration of the renal threshold would not explain the low blood chlorides observed. The diminished output of chlorides in the urine appears quite analogous to that observed in pneumonia [16] and is not primarily renal. When the plasma chlorides fall below the renal threshold excretion ceases. As the blood chlorides again rise above the renal threshold, excretion begins.

The low values of the whole blood and plasma chlorides might also be attributed to blood concentration. The sodium chloride content of normal plasma varies from 560 to 640 mg. per hundred cubic centimeters, while that of the corpuscles is about 310 mg.[23] Any factor that alters the proportion of cells to plasma in circulating blood changes the value of the whole blood chlorides. It may be seen in the determinations presented (fig. 3) that the whole blood chlorides remained low even after the plasma volume had returned to normal limits, and the red blood cell count and hemoglobin revealed no concentration. Were the low chloride values of whole blood due to a simple process of concentration, no alteration in the plasma chlorides would be anticipated. However, in those cases in which plasma chlorides were determined, the depression of the chlorides (fig. 4) was as striking as that observed in whole blood.

It might also be urged that the fall in blood chlorides may be due to the loss of sodium chloride at the site of the burn during the development of edema. The blood depletion would continue until tissue chlorides were mobilized. This might seemingly explain the initial fall which is occasionally seen in extensive burns, but were this the true explanation, the normal balance would be reestablished in a few hours. In case 1 (table 1) the intensity of the thermal agent was sufficient to cause a marked edema but it caused little tissue destruction. Were the lowering of blood chlorides due to simple edema, a fall would be anticipated in this instance; however, no change occurred. Were this the explanation of the phenomenon observed, the lowering of the blood chlorides would be transient, but from the other cases investigated it seems that the low values persist as long as sloughs are present.

Finally, it might be asserted that the persistent low blood and plasma chlorides are due to loss of chloride and plasma in the wound. Undoubt-

23. Norgaard, A., and Gram, H. C.: Relation Between the Chloride Content of the Blood and Its Volume Per Cent of Cells, J. Biol. Chem. **49**:263-278 (Dec.) 1921.

edly some loss takes place by this route, but it does not entirely explain the picture. In case 13, in which the burn was practically all third degree, the blood chlorides remained at such a low level that there was almost a complete suppression of urinary chlorides. When all the sloughs separated, leaving a raw granulating wound (fig. 8) much more favorable for the loss of plasma, the blood chlorides, instead of remaining at a low level as would be anticipated, immediately rose. There was a parallel rise of the urinary chlorides and later an outpouring of chlorides (fig. 6), which was greater than the daily intake. Finally, a fairly normal ratio between the sodium chloride intake and output would not become established until healing was complete if this explanation were correct.

The chloride metabolism in burns is a complex mechanism, undoubtedly involving a number of factors. These have been enumerated and

Fig. 8 (case 13).—Granulating wound on twenty-fourth day.

no one of them alone explains satisfactorily the alterations noted. There probably is some direct loss of sodium chloride from the lesion, but this does not appear to be great, because the blood chlorides reach normal and chloride excretion in the urine begins as soon as the sloughs separate, although a granulating wound still remains.

In lobar pneumonia there is sodium chloride retention that is not accounted for by analysis of the involved lung tissue.[15] The chloride seems rather to be concealed in combination with all the tissues and at the crisis there is a sudden outpouring of chlorides. A quite similar elevation of blood chlorides and the appearance of large quantities of sodium chloride in the urine took place in the case detailed in table 3 as soon as the sloughs separated. This observation suggests that sodium chloride had been stored in the tissues.

The clinical condition of the patients under discussion has been reflected better by the level of the blood chlorides than by observations of

the nonprotein nitrogen. The analogy between intestinal obstruction, which is thought to be an intoxication due to some protein derivative, and the toxemia of burns is a close one. The clinical picture, the finding of increased protein catabolism, and alterations in the chloride metabolism are strikingly similar. Haden and Orr [22] have presented the conception that in intestinal obstruction sodium chloride combines with the primary toxic material before it has an opportunity to cause tissue protein destruction. In a series of admirable studies they have demonstrated the protective and detoxifying effect of sodium chloride in intestinal obstruction. From the present observations and the analogy with intestinal obstruction it would seem that a rational therapy in burns would consist of the judicious administration of sodium chloride in an attempt to correct the metabolic deficiency.

SUMMARY AND CONCLUSIONS

In observations on the chloride metabolism of thirty-one burned patients, the lowering of the whole blood and plasma chlorides was significant.

The fall in the blood chlorides was not wholly explained by alteration of the renal threshold, diet, fever, exudation, blood concentration, nor by vomiting.

There was suggestive evidence that retention of sodium chloride took place.

The diminished sodium chloride output in the urine was not due to primary kidney change but rather to a lowering of the plasma chlorides to a level below the renal threshold.

The disturbance of chloride metabolism seemed proportionate to the amount of tissue devitalized.

The retained chloride was not present in the blood in some undetermined form.

There was evidence of an increased protein catabolism.

The observations suggest the administration of sodium chloride to correct the deficiency.

CORRECTION

Dr. Albert J. Scholl, Los Angeles, reports an error in the Review of Urologic Surgery appearing in the April issue of the ARCHIVES OF SURGERY. In the editorial note on page 937, the statement to the effect that Dr. Hager of the University of Wisconsin has had an extensive experience in the treatment of schistosomiasis in Santo Domingo should read:

"Hager of the University of Wisconsin has had considerable experience in the treatment of tropical diseases indigenous to the West Indies."

A REVIEW OF UROLOGIC SURGERY

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(Continued from page 152)

BLADDER

Diverticulum.—Gayet and Cibert [37] reviewed their cases of diverticulum of the bladder. They state that they are inclined to modify their previous opinion that congenital diverticula were far more frequent than acquired diverticula. In twenty-two cases they found only five in which the disease was probably congenital. In the other seventeen there was an obstacle to the flow of urine; in ten cases the obstacle was prostatic adenoma, in six it was a stricture and in one a supurative cyst of the prostate. All patients were males. One case was interesting to study from an etiologic standpoint; there was no kidney, no ureter, no seminal vesicle or vas deferens on the left side. Instead there were two large diverticular pouches on the left side of the bladder. Stiles reported a somewhat similar case. The authors state, "Certain diverticula, of rather rare occurrence, are due to incomplete development of ureteral buds, or seminal buds." They also mention the following hypothesis, which had been first stated by Paul Delbet: Congenital diverticula may have their point of origin in the nondevelopment of a double ureter. Gayet and Cibert do not wish to insist on these hypotheses, because of the still unsettled state of knowledge of the embryology of the bladder; they state that an area particularly favorable to the development of diverticula exists in the region of the ureteral meatus which may in certain cases be included in the malformation, appear on the edges of the diverticular orifice or even be situated in the diverticulum itself. Noninfected, nonadherent diverticula are rare; most often there is some peridiverticulitis. Often the

37. Gayet, G., and Cibert, J.: Quelques cas de diverticules de la vessie, J. d'urol. méd. et chir. **19**:473-505, 1925.

ureter pressed by the pocket is dilated above and the corresponding kidney is dilated and septic. In fifteen cases of Gayet and Cibert death occurred in six cases in which operation was not performed and in three of nine cases in which operation was performed. In the former cases the diverticula, pyuria and fistulas rendered the prognosis serious, whereas in the latter either the disease was definitely cured or, at least, the more severe symptoms were relieved. The authors agree on the necessity of a radical operation and particularly on the great importance of early diagnosis.

Mercier [38] states that interrupted micturition is not characteristic of diverticulum of the bladder alone; it may occur with an accentuated interureteral bar. Its mechanism is not the same in the latter as in cases of diverticulum. The mechanism when a bar is present in somewhat similar to that observed in the watergate of a sluice. During the first micturition, under the influence of contractions, the bar becomes progressively prominent and shuts off anteriorly a marked depression from which urine cannot flow. At rest, this crest diminishes in size and urine then escapes towards the vesical neck; a second micturition will evacuate the fluid which has passed in front of the bar. This mechanism depends on a number of conditions; the bar must be sufficiently developed and vesical contractility good. When the interureteral bar is moderately prominent, the obstacle is sufficient to hold back of it a certain quantity of urine during urination. In extreme cases marked hypertrophy of the trigon may enclose a definite and slightly contractile depression, causing a constant amount of residual urine.

Ward,[39] in considering vesical diverticulum, concludes that it may be entirely congenital in origin, but that there also is usually an obstruction of the vesical neck which causes it to become large enough to produce symptoms. In one of Ward's cases, that of a boy aged 15 years, there was a diverticulum without any obstruction. The commonest symptoms result from infection of stagnant urine in the pouch. It is not surprising that inflammation should occur, and that calculi should form; for, although the wall of the sac usually contains muscle fibers, this musculature is always inferior in development to that of the bladder itself. The ring of muscle, which is often seen around the orifice, has only some of the functions of a sphincter, and these only in a very imperfect degree. Therefore, when the patient micturates, the bladder empties itself in two directions, namely through the internal urinary meatus into the urethra, and through the partly contracted

38. Mercier, O.: De la miction en deux temps dans la barre interurétérale, J. d'urol. med. et chir. **20**:97-102, 1925.

39. Ward, R. O.: A Clinical Study of Eleven Cases of Vesical Diverticula, Brit. J. Surg. **13**:144-157 (July) 1925.

orifice into the diverticulum. When the bladder is empty the diverticulum sometimes discharges its contents, but usually the act is very incompletely performed, and probably, in every case, some urine remains in it, even if special postures are adopted to encourage drainage by gravity, and, indeed, even after catheterization.

The cystoscope and cystogram provide accurate means of diagnosis. Palliative measures are unsatisfactory and excision is the only satisfactory means of cure. Results of such operations are good but care must be taken that coexistent obstruction is not overlooked. When obstruction is present it must be suitably dealt with.

[ED. NOTE.—It is very important that the accompanying obstruction of the bladder be dealt with properly. Some urologic surgeons state that if the obstruction is removed the diverticulum need not be disturbed. This is a somewhat radical view but it unquestionably holds true in the cases of small uninfected pouches. Removal of the obstruction, whether by means of a prostatectomy or by excision of the vesical neck, increases the operative risk only slightly. In a series of fifty recently reported cases in which the diverticulum alone was excised, three (6 per cent) patients died. In a second series of thirty-seven cases in which excision of the diverticulum and prostatectomy were performed, three (8.1 per cent) patients died.

At times the suprapubic vesical wound is slow to heal after an operation for the removal of a diverticulum. While this may be due to the presence of an obstruction at the neck of the bladder, the latter may sometimes be impossible to demonstrate, and we have been inclined to feel that the poor contractility of the wall of the bladder and the vesical deformity might be responsible for the persistent suprapubic urinary sinus.]

Jarosz [40] reports a series of cases of diverticulum of the bladder from Hildebrand's Clinic in Berlin. Pagenstecher states that congenital diverticula develop on the basis of a second bladder anlage. The musculature of the bladder withstands the pressure of urine for a time but later gives way to the formation of a sac or diverticulum. The diverticula are prone to develop first in the region of the ureteral outlets, next in the anterior or posterior wall, on the side walls, and last in the dome of the bladder. Blum states that congenital diverticula develop either through a defect in the formation of the bladder, an anomaly in the fetal anlage or as a result of urinary retention in fetal life. The developing type of diverticulum forms in later life as a result of straining on urination and an increase in the intravesical pressure. The condition may result from stone, prostatic hypertrophy,

40. Jarosz, H.: Zur Kenntnis der Harnblasendivertikel, Ztschr. f. Urol. **19**: 722-733, 1925.

urethral stricture or even from phimosis. Zacharisson found a case in a boy, aged 21 months, which was caused by a marked phimosis. Spinal diseases may also cause urinary retention, muscular spasm and the formation of a sac. Diverticula may also be associated with hernia. Englisch reported ten single and six bilateral diverticula found in hernial sacs. There is an increasing number of cases being diagnosed since the perfection of diagnostic methods. In 1901 Durrieux found 194 cases in an extensive review of the literature. Cholzoff in 1911 reported seventy cases of congenital diverticulum and Englisch reported 250 cases of stone forming in diverticula. Jarosz reports nine cases. In two cases in which operation was performed, one for removal of the diverticulum and prostatectomy and the second for removal of a stone from the diverticulum, death ensued. In a third case, in which the diverticulum was in a hernal sac, operation was performed successfully. In the remaining cases surgical treatment was not instituted. In one there were multiple diverticula, in another the diverticulum was complicated by carcinoma.

[Ed. Note.—These cases were observed during a period of fifteen years. During the same period 181 cases of prostatic hypertrophy, twenty-four of vesical stone, sixty-one of vesical tumor and thirty of other surgical diseases of the bladder were observed. There was a small number of cases in which operation was performed and most of these occurred from ten to fifteen years ago; the results obtained were in accordance with the results for similar operations of that period. Since that time there have been remarkable advances in the diagnosis and surgical approach in cases of lesions of the bladder. In the earlier cases in which operation was performed the condition was often discovered accidently, and the operation was carried out without consideration of the complicating lesion and, at times, of the presence of marked infection. The mortality was high and the operative results were only fair. Recent methods of urologic diagnosis, however, make it possible to recognize the disease, the associated lesion and the infection, and to suggest the type of surgical procedure that will produce the most satisfactory results in a given case. A review of the theories of the formation of diverticulum is given.

Vesical diverticula are probably due, as Jarosz states, primarily to embryologic defects in the bladder, either a weakening of the musculature, usually at the base of the bladder, or a definite hiatus in the wall of the bladder. Targett asserts that they are due to an interruption of the muscle fibers in the base of the bladder by the entrance of the large vesical arteries in this region. The actual distention and dilatation of the sac probably result in most cases from obstruction to the outlet of the bladder. Diverticula are often seen in young children and occasionally in the fetus. In a 5 months embryo, seen at the Mayo Clinic,

two definite diverticula were found, one in the region of each ureteral orifice. The one near the right orifice was composed of all the coats of the bladder and was 1 cm. in depth. Kelly states:

> Diverticula of the bladder are usually formed from small preexisting pouches or hernias in the bladder which become enlarged by pressure and later come into prominence through stagnation of urine and inflammation.

According to Hinman, diverticula result from anatomic, pathologic and mechanical factors, and in this sense the condition is acquired. He states:

> A mild chronic urinary obstruction in association with the necessary anatomic or pathologic predisposing condition of the bladder wall is particularly conducive for the development of diverticula.

The mortality, both without and with operation, up to recent years has been high. Englisch, in 1894, found that in 83.1 per cent of the reported cases of vesical diverticula the patients had died as a result of the abnormality. At this time few operations were performed on the bladder, and in most cases the diverticula were probably seen only in the late stages. In 1910 Fischer collected records of forty-eight cases in which, with and without operation, thirty-two patients (66.7 per cent) died. Of twenty-eight patients subjected to operation, eight (40 per cent) died. In 1922, Kneise and Schulze compiled records of thirty-five cases from the German literature and added eighteen of their own, in which radical operations had been performed. Four patients (7.7 per cent of fifty-two) died following operation.]

Bladder Tumors.—MacKenzie [41] reports 288 cases of vesical neoplasms from the Royal Victoria Hospital. Table 2 gives the method of treatment and the results obtained.

MacKenzie liberates the bladder by extraperitoneal resection which permits drawing the bladder forward and out of the abdomen. The peritoneal fold is carefully separated through a suprapubic incision in the median line, the urachus is liberated, clamped, cut, and the upper stump ligated. Traction is then applied to the lower stump to facilitate the separation of the peritoneum from the posterior wall of the bladder. If the case is one of benign papilloma, complete destruction with cautery well into the wall of the bladder is sufficient, the cauterization extending through the wall of the bladder. If the condition is malignant the underlying wall of the bladder is widely excised. If the ureteral orifice is involved the ureter is transplanted. When radium was used emanation seeds were employed and inserted through a hollow needle. When deep roentgenologic treatments were given, they consisted of a series

41. MackKenzie, D. W.: Bladder Neoplasms, Surg. Gynec. Obst. **41**:773-778 (Dec.) 1925.

TABLE 2.—*Treatment and Results in Two Hundred and Eighty-Eight Cases of Vesical Neoplasm (MacKenzie)*

	Cases	Total
Papilloma of bladder, malignant	39	
Repeated fulguration:		
Cured	12	
Improved	7	19
Cystotomy and cauterization:		
Cured	5	
Improved	1	6
Excision:		
Cured	4	
Improved	2	6
Treatment by cautery and radium:		
Cured	4	
Improved	1	5
No treatment	3	3
Carcinoma	78	
Inoperable, no treatment	27	27
Excision:		
Cured	7	
Recurrence	6	
Died	1	14
Excision and cauterization:		
Cured	2	
Improved	1	3
Excision and treatment with radium:		
Cured	2	
Improved	2	4
Treatment by cautery and radium:		
Cured	4	
Recurrence	1	
Died	1	6
Excision and transplantation of ureter:		
Cured	1	1
Excision and transplantation of ureter and treatment with radium:		
Died (this patient died from metastasis five months later)	1	1
Cauterization and fulguration being only palliative efforts in advanced cases:		
Cured	1	
Recurrence	4	
Not improved	5	
Died	1	
Deep roentgen-ray, inoperable cases:		
Improved	2	
Not improved	3	
Died	1	6
Suprapubic drainage for advanced inoperable conditions:		
Not improved	1	
Died	4	5

of four treatments of 200 kilovolts, 5 milliamperes, distance 40 cm. and exposure sixty minutes. The rays were filtered through 1 mm. of copper and 1 mm. of aluminum. One exposure was given over the symphysis, one over the sacrum, and one over the right and left sacroiliac joints. This was repeated at the end of six weeks.

Fullerton [42] draws attention to the confusion that exists at present in classifying epithelial tumors into benign and malignant groups and recommends Broders' classification, which depends on the proportion of differentiated to nondifferentiated cells in the section. The differentiated cells resemble those of the epithelial lining of the normal bladder. The undifferentiated cells are the spherical and irregular cells, with prominent nucleoli. Four grades are recognized, the first being one-fourth undifferentiated, the second one-half, the third three-fourths, and the fourth entirely composed of undifferentiated cells.

Fullerton further calls attention to the large proportion of late diagnoses that occur on account of the negligent way in which these patients are treated without investigation for years. Vesical symptoms, and especially hematuria in late adult life, are too serious to be trifled with and demand the most prompt and careful urologic investigation.

All tumors of the bladder are more common in the male than in the female. In the author's series of 103 cases 70 per cent were in males. Innocent tumors may become malignant.

In his earlier experience Fullerton treated all simple papillomas by open operation. He has used transvaginal, transperitoneal and suprapubic extraperitoneal methods of approach. The latter is the method of choice. In villous tumors, diathermy is useful and may be applied through the cystoscope.

In carcinoma of the bladder, results are disappointing. To be of use, resection must be extensive. Radium and deep roentgen rays have not found an important place in treatment in his experience.

Extrophy.—McCarthy and Klemperer [43] report a case of malignant disease and exstrophy of the bladder. The growth, which was of the cauliflower type, covered the bladder and was treated by diathermy. No attention was paid to either ureteral orifice. The tumor recurred in six months and was again treated with diathermy. One year later there was a second recurrence and it was decided that total cystectomy was necessary. As a preliminary measure bilateral ureterostomy was thought necessary. The right ureter was dilated so that it carried a no. 30 French tube. Later it was found that the left kidney was prac-

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42. Fullerton, A.: The Treatment of Bladder Tumors, Irish J. M. Sc., pp. 243-258, June, 1925.

43. McCarthy, J. F., and Klemperer, Paul: Report of Interesting Case of Exstrophic Bladder with Neoplastic Implant, J. Urol. **14**:419-427 (Oct.) 1925.

tically destroyed. The left kidney was removed under local anesthesia. Later the bladder was removed under sacral anesthesia. Convalescence was uneventful and the patient's general health became much better. Histologically the tumor was adenomatous in structure, resembling the adenomas of the large intestine. Histologic examination of the extirpated bladder revealed, in many places, glandular structures. Among twenty-one cases of carcinoma of the exstrophic bladder reported in the literature, the tumor was adenocarcinoma with the characteristics of intestinal carcinoma in fifteen cases, squamous cell carcinoma in four cases, and in two no histologic report was made.

[ED. NOTE.—Vrolik in 1822 first remarked on the curious mucous covering of the exstrophied bladder. Lichtheim in 1873 mentioned a complete glandular covering on an exstrophied bladder observed by him. Enderlen also observed this condition in several cases. He stated that it is impossible to determine at what age the condition appears; he found it in an infant aged 18 months. Ehrich explains the presence of the glandular covering over exstrophied bladders from an embryologic standpoint. The bladder and intestines both come from the same source; due to its unusual situation the bladder has not the stimulation to change over to the usual type of transitional epithelium but retains that of the intestines. The work of Haché supports this theory; he compiled six cases of exstrophy of the bladder in which the intestine and bladder were united, the intestinal opening persisting on the surface of the misplaced bladder. Enderlen's studies seem to disprove Ehrich's theory. In a number of exstrophied bladders from infants who died at birth he found normal transitional epithelium. Evidently the glandular formation is not a result of embryonic changes but occurs in response to some stimuli developing after birth.

In exstrophied bladders from adults extensive glandular formations, such as reported in the case described, may be found in almost any area. The normal transitional epithelium has practically disappeared and various gradations of metaplastic changes may be traced from the normal epithelium to solid glandular masses and extensive squamous cell coverings. This process probably results from a combination of metaplasia with hyperplasia of the normal glands often seen in the mucosa of the bladder. Such glands, which generally consist of a few cells only, were well described by von Brunn and von Limbeck. Later Stoerck and Zuckerkandl described a glandular cystitis which developed into malignant disease as a result of constant irritation. In exstrophy of the bladder the exposure to the air, the constant irritation of the clothing, the frequent trauma and persistent infection, with the possible need for a protective mucous covering or mucous secretion, furnish an excellent stimulation to cellular hyperplasia. The almost constant association of squamous cell covering, a type of growth which is rarely

formed unless a protective surface is necessary, gives evidence of the extent of the irritation and trauma. The mucosa of these exstrophied bladders contains areas gradually shading off from fairly normal to definitely malignant tissue. It is of interest that the majority of tumors forming on exstrophied bladder are adenocarcinomas. This is in marked contrast to the types of tumors occurring in normally situated bladders; adenocarcinoma makes up only about 2 per cent of such growths. There were five adenocarcinomas in 333 tumors of the bladder treated at the Mayo Clinic.]

Urinary Retention.—Michon [44] reviewed a series of thirty-four cases of urinary retention which occurred in 195 patients who had been operated on for lesions in the lower part of the abdomen. He stated that it is not desirable to carry out the usual repeated evacuation of the bladder by catheter. Many patients who are catheterized are later unable to void normally until they get out of bed, and it is rare to find at that time normal micturition and clear urine. Michon advises two methods of relief for retention. In six cases he gave the patient hexamine which was quite effective in preventing infection. In the remaining cases he injected a solution of bōric glycerin into the bladder. Glycerin instillation is quite uncomfortable at times and necessitates catheterization but it usually produces good results and Michon considers it the most desirable method of treating retention.

Voelcker [45] comments on the prominence given in recent literature to cicatricial and callous thickening of the neck of the bladder. Often the sound or bougie will show no obstruction to passage but a thickening of the sphincteric region will lead to difficulty in completely emptying the bladder. He feels that the real obstruction to the urine comes from a concomitant thickening of the vesical mucosa adjacent to the thickened sphincter. This protrudes to some extent through the urethral orifice and thus partially cuts off the urinary outlet. Incision of the sphincter by means of a sphincterotome or with the knife by suprapubic incision most frequently leads to cure but some cases require entire excision of the thickened sphincter. Incontinence has not been found to be a complication after such operations. One must assume that the layer of smooth muscle lying next higher comes into function as a sphincter in such cases.

[ED. NOTE.—The type of case mentioned corresponds to contracture of the vesical neck in its various phases. Our attention in this country has been brought to this condition largely through the extensive work

44. Michon, L.: Le traitement de la retention d'urine postoperatoire, Presse méd. **33**:1556-1558, 1925.

45. Voelcker, F.: Die Sklerose des Blasenschliesmuskels, Ztschr. f. urol. Chir. **17**:103-104, 1925.

of Caulk in this field. The use of the cautery punch as a therapeutic measure is gaining ground and in the majority of such cases seems to produce satisfactory results.]

Extroversion.—Bryan [46] reports a case of complete extroversion of the bladder in a girl, aged 2½ years. The child had enjoyed good health up to three days before it was seen by Bryan, when while voiding she screamed out with pain. At this time the mother noted a red swelling at the vulva. The family physician reduced this swelling under chloroform anesthesia and told the mother that it was probably the bladder. When seen in hospital the vulva was reddened, some of the veins engorged and the urethra appeared to be dilated. The next day under anesthesia the bladder was washed, a cystoscopic examination made and a cystogram taken. This showed a dilated right ureter which was filled with the cystogram medium. Subsequently the swelling reappeared many times, always in the order of superior wall, followed by the fundus, floor and trigon. Two ureters could be seen on the trigon, a normal left and a dilated slitlike orifice of the right situated quite near the left. After a month of observation and examination it was demonstrated that the bladder was large, thickened, hypertrophied and crisp from repeated hyperengorgements of forcible eversion; the large right pyoureter (associated most likely with an ureterocele) was seen; the right kidney was rudimentary or nonfunctioning and its retention products with that of its ureter were found to be giving rise to severe hyperpyrexia and prostration; the condition of the left kidney was satisfactory and its 80 per cent phenolsulphonphthalein return was thought to justify surgical attack on the right side.

At operation a double kidney was found in the right side, with both ureters dilated. One ureter ended high on the posterior wall of the bladder and the other at the slitlike orifice near the left ureter. The child recovered satisfactorily and at later cystoscopic examinations a cone of ureter was found bulging down from the site of the ureter placed high on the posterior wall. This bulging ureter was the probable exciting cause of the extroversion.

Fistula.—Tant [47] reports the case of a patient, aged 26 years, who had had an appendectomy and a hysterectomy performed two years previously. Following the operation she rarely urinated normally, most of the urine draining through the vagina. An examination five months after the operation revealed two vesicovaginal fistulas. Cystoscopic examination revealed the two small orifices of the fistula in the region

46. Bryan, R. C.: Complete and Repeated Extroversion of the Bladder Through the Urethra, Associated with Double Right Kidney and Ureter, J. Urol. **14**:153-181 (Aug.) 1925.

47. Tant: A propos du traitement de la fistule vésico-vaginale, Bruxelles méd. **5**:1410-1411, 1925

of the left ureteral orifice. The edges of the fistulous tracts were curretted through the vagina, the patient was placed on her abdomen and a permanent urethral catheter inserted. Ten days later, the catheter was removed and no further urine escaped through the fistulas.

Schockaert [48] reported a case of sigmoidovesical fistula which had been present for twenty-three years, having resulted from a subtotal hysterectomy. Gas and feces passed through the urethra continually and the patient had a severe cystitis and irritation of the external genitalia. The fistula extended deep into the pelvis close to the left ureter. Schockaert did not make a complete dissection of the fistula, as he feared injury to the ureter or a peritoneal infection from opening the sigmoid. A simple ligation of the fistula with silk effected a cure; three years later there had been no further trouble.

Cystitis.—Cairns,[49] in reviewing eighty cases of cystitis at the London Hospital, found that there were two main clinical types: one in which the disease tended to clear up quickly, either spontaneously or with simple treatment, and the other in which the disease became chronic. In almost all of the chronic cases the cystitis was maintained either by a persistent infection from the kidney or by the presence of residual urine in the bladder. In all the cases there was pus in the urine and the result of bacteriologic investigation showed that colon bacilli occurred with much greater frequency than any other organism. In 35 or 40 per cent of the cases the clinical course indicated that the cystitis was secondary to infection of the kidney or renal pelvis; it was impossible to determine accurately the source of the infection in the other cases. Cystitis of the resolving type was associated with prostatitis in a few instances, but the relationship between these foci of infection was not clear. In some cases the infection undoubtedly came from the kidney, in others possibly from the prostate. There remained, however, many cases in which it was impossible to determine the source of the infection. The chronicity of cystitis is due to a number of conditions. In rare instances it is due to a solitary ulcer of the bladder, a condition of unknown etiology. Usually it is due either to persistent infection from the kidney or to the presence of retained urine in the bladder. A persistent focus of infection in the renal pelvis may give no clinical signs. Evidence obtained by cystoscopy is frequently of great value in the detection of such foci. If the lesion of the renal pelvis is treated efficiently, the cystitis will clear up. Any variety of retention of urine may produce progressive cystitis. The successful treatment depends entirely on the establishment of complete drainage of the bladder either

48. Schockaert, R.: Un cas de fistule sigmoide-vésicale postopératoire, Bruxelles méd. **6**:104-105, 1925.

49. Cairns, H. W. B.: Observations on the Etiology and Treatment of Cystitis, Brit. J. Surg. **13**:78-92 (July) 1925.

by natural or artificial means; irrigation of the bladder is of great service. When cystitis occurs in a case of unrelieved acute retention there is grave danger that it will be followed by ascending pyelonephritis, a condition that is usually fatal. When it is realized that in all cases of retention of urine immediate and complete relief is necessary, then only will ascending pyelonephritis (the occurrence of which is a grave reflection on the teachings and practice of surgeons of today) cease to be common. Drainage of the distended bladder is an operation of greater emergency than that of drainage of a pelvic abscess. Finally, cystitis, although a distinct clinical entity, is usually secondary to some other lesion of the urinary tract. It should not be treated empirically; the exciting and predisposing causes should be sought by a thorough investigation of the whole of the urinary tract. When these causes have been dealt with, the inflammation of the bladder will subside of its own accord.

[ED. NOTE.—Cases of simple, apparently primary cystitis are not uncommon in elderly women. There are usually several ounces of residual urine and the mucosa of the bladder is chronically inflamed; the urine in the bladder contains a large amount of pus, while in most cases the urine from the kidneys is clear and without infection. This type of cystitis usually responds readily to lavage of the bladder. In elderly men cystitis usually is associated with obstruction at the neck of the bladder and more or less residual urine. In rare cases, especially if onset is acute, there is no residual urine and no obstruction; it is in this type of case that hexylresorcinol is most efficacious, particularly when combined with lavage of the bladder with mercurochrome-220 soluble.]

Syphilis.—Blanc and Negro [50] report a case of a woman, aged 37, who, for five months, had had symptoms of cystitis. There had been no hematuria, but marked loss of weight. The patient's most typical complaint was the passage of gas through the urethra with occasionally small blackish and purulent solid particles. She had been treated for syphilis for several years. A cystogram revealed an irregular piriform bladder. After the bladder was emptied the rectum could be seen filled with the opaque substance, which later passed through it. A preliminary diagnosis of perforated malignant growth was made, but as the patient was syphilitic, antisyphilitic treatment was instituted and prolonged for almost a year. She gained considerably in weight and the vesico-intestinal fistula closed completely. Only one similar case could be found in the literature, that of Picot.[51] The interesting features of Blanc and

50. Blanc, H., and Negro, M.: A propos d'un cas de syphilis vésicale (fistule vésico-intestinale), J. d'urol. méd. et chir. **19**:513-520, 1925.

51. Picot, Gaston: Un cas de syphilis vésicale et urétrale, J. d'urol. med. et chir. **2**:693-698, 1912.

Negro's case were: (1) the sex, this lesion being exceptional in women, because of anatomic reasons, and the impossibility of determining whether the lesion had its origin in the intestine or the bladder; (2) whereas feces passed through the urethra, apparently no urine came through the rectum; (3) the erroneous diagnosis, and (4) the useful aid of cystography.

PROSTATE

Prostatectomy.—Delore, Rougemont and Creyssel [52] state that great benefit is derived from a combined method of the suprapubic and perineal routes in certain cases of prostatectomy, for example when the hypertrophy is excessive and the transvesical extraction requires a fragmentation of the gland or manipulation provoking great trauma or hemorrhage. The perineal stage will thus often be decided on in the course of the operation and only in rare instances will it be decided *a priori* to do the prostatectomy in two stages. This may be indicated if the gland has been inflamed for a long time or submitted to prolonged preliminary radium or roentgen-ray treatment. The authors report the procedures in a case as follows: (1) fruitless attempt of hypogastric enucleation; (2) the suprapubic route momentarily abandoned; the perineal region prepared, the perineum incised either medially or transversely and the perirectal space separated, and a small opening made in the urethra at the level of the prostatic end and the finger inserted in that opening; (3) by combined manipulation, of the abdominal and perineal fingers, extraction of the prostate through the abdominal incision, and (4) warm lavage and continuous through and through drainage, the drain being removed on the third day and replaced by a retention catheter. The perineal incision heals readily and the postoperative course is similar to that of a simple suprapubic operation.

[Ed. Note.—It is only rarely that a perineal incision is necessary. If it is necessary to elevate the prostate from below it can readily be reached from its rectal surface.]

Salvini [53] reviews 180 cases in which suprapubic prostatectomy was performed by Professor Marion in the Service Civiale during a period of about three years. There were thirteen deaths, a mortality rate of 7.2 per cent. There was one serious case of peritoneal infection, eight cases of marked hemorrhage, occurring within three days after operation,

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52. Delore, X.: De Rougemont, J., and Creyssel, J.: De l'utilité de la voie combinée hypogastrique et périnéales dans certaines prostatectomies difficiles, J. d'urol. med. et chir. **19**:398-401, 1925.

53. Salvini, P.: Resultats immédiats et éloignés de la prostatectomie suspubienne chez 180 malades opérés de 1921 au 30 Juin, 1924, J. d'urol. med. et chir. **20**:103-124, 1925.

two cases of tearing of the membranous urethra with late formation of a urethral stricture and two cases of infected wound. There were two cases of epididymitis, either an exacerbation of a previously existing infection, or, as Marion thinks, a condition due to a failure to section the vas, a practice he performs in every case of prostatectomy in order to avoid epididymitis. In sixteen of the 180 cases the fistula had to be closed surgically; Marion states that fistulas that do not close in thirty-five days after operation should be resected, liberated from the edges of the bladder and sutured in three layers. There were two cases of phlebitis. In two cases the passage of the catheter was difficult, and in two cases it was impossible on account of scarring of the vesical extremity of the urethra. In both cases Marion had to reestablish the permeability by the use of a béniqué sound guided by one finger introduced into the prostatic cavity through the suprapubic wound. All the patients after removal of the permanent catheter were able to void. In fifty-seven cases further catheterization had to be done, in forty-two the bladder was emptied completely and in fifteen partially, with a residue of urine varying from 20 to 225 cc. The urine began to clear usually from ten to twenty days after operation. Late results were obtainable in 148 cases; in eleven micturition was slightly painful, in none had the catheter been used, in 144 there was night frequency, in thirteen residual urine varying from 30 to 90 cc., and in nineteen there was cloudy urine. In twenty-five sexual function had diminished; all the patients were more than sixty-two years. Three patients developed urinary calculi; two of these had had stones before operation. Four patients had incrusted cystitis; a perfect cure was obtained by suprapubic curettage. The few patients who were incontinent after removal of the catheter recovered normal function following urethral dilatation. Salvini states that prostatectomy influences the bladder favorably but that it does not aid in the regression of any disease of the kidney. Dysuria disappears, but polyuria continues. Two patients died a few months after operation from interstitial nephritis. Only eight patients did not improve in general health; they had had partial retention of long standing before operation. One patient who had had several attacks of epilepsy was cured after prostatectomy. One patient committed suicide; Marion has noted several cases of neurasthenia following prostatectomy.

Michon [54] reports on the benefits and the inconveniences of the two-stage prostatectomy. The first stage of the operation releases the vesical distention which destroys renal function, and also reduces the vesical infection and the later operative risk. Chronic retention frequently causes distention which also affects the kidney and produces a toxemic

54. Michon, E.: De la prostatectomie en deux temps, Semaine d. hôp. de Paris **2**:47-50, 1925.

state with high urea retention. In order to reduce this primary distention one of two procedures may be followed, catheterization or suprapubic drainage. Catheterization must be repeated frequently and often causes a dangerous infection; suprapubic drainage, done under local anesthesia, with gradual emptying of the bladder, is less likely to cause infection. From several weeks to several months should elapse between the two stages. If infection or calculi are present suprapubic drainage is the only satisfactory procedure. The inconvenience of the two-stage operation is primarily the greater difficulty in removing the prostate at the second stage as the plane of cleavage has partly disappeared, and if the drainage has been maintained for a long period of time the fistulous tract has become thickened and fibrous and it is necessary to resect the fistula in order to obtain a good closure of the bladder. With the two-stage operation the patient is incapacitated for a much longer period. Michon concludes that if the patients are young, have normal blood urea, and have no infection or only slight infection, the one-stage operation is the more satisfactory.

[Ed. Note.—Table 3 taken from the recent report of Liebig [55] is interesting in regard to the mortality in one and two-stage suprapubic operations.

Table 3.—*Mortality in One and Two-Stage Suprapubic Operations (Liebig)*

Suprapubic (one-stage)	Number	Deaths	Per Cent
1912 to 1916	2,958	248	8.38
1917 to 1922	2,379	189	7.9
	5,337	437	8.1
Suprapubic (two-stage)			
1912 to 1916	276	28	10.2
1917 to 1922	507	22	4.3
	783	50	6.3

Unquestionably the two-stage operation reduces the operative risk, the hemorrhage usually occurring with prostatectomy is much less and the organism has had time to readjust itself to a new condition of drainage and exposure before the more serious procedure of removal of the gland is performed. One of the most important features of a preliminary drainage is that the patient develops at least partial immunity to his own type of colon bacillus infection; after the second operation if a cysto-ureteropyelonephritis develops it is usually mild and the patient is, with his increased resistance, well able to stand the infection.]

55. Liebig, Fritz: Die Prostatahypertrophie, Ztschr. f. Urol. **17**:593-613; 625-659, 1923.

Postoperative Hemorrhage.—Legueu and Garcin [56] state that the onset of postoperative hemorrhage following suprapubic prostatectomy may occur from two to three or four days after operation; rarely it may occur on the tenth or twelfth day. The hemorrhage may be due to several factors, such as the size of the adenoma; the large easily enucleated tumors bleed readily. The type of the operation also is important; there is much less bleeding in the two-stage operation, especially if a long period has elapsed between the two operations. Ether and gas are likely to cause hemorrhage during the operation; chloroform causes less and apparently spinal anesthesia markedly reduces the amount of hemorrhage during the operation. On the other hand spinal anesthesia often provokes marked hemorrhage several hours after operation on account of a later or secondary vasodilatation. Local anesthesia does not affect loss of blood. In most of Legueu's cases the prostatic cavity was packed after operation; this has several disadvantages as there is considerable pain connected with a distention of the cavity and with removal of the packing and also the danger of infection is increased on account of the irregularity and power of absorption of the lacerated prostatic bed. Hemostasis itself is not perfect in a packed wound as a small clot of blood may be disturbed in withdrawing the strip of gauze and cause a new hemorrhage. Because of this Legueu and Garcin have recently tried a new method of controlling hemorrhage; they endeavored to increase the coagulating power of the blood. The work is based on the fact that after prostatectomy the blood has the same consistency and follows the same course as it does following any severe hemorrhage; it passes through a period of hypocoagulability lasting from four to five days and is followed by a period of hypercoagulability lasting from three to four weeks and reaching its acme on the ninth day after operation. They tried injections of a proprietary drug that increases the coagulation of the blood, which definitely reduced the hemorrhage and allowed the removal of packing on the second or third day; they also used calcium chloride in 5 per cent solutions, injecting from 10 to 20 cc. before operation. The results were satisfactory in ten cases in which packing was not necessary. In two other cases the results were unsatisfactory. At present Legueu and Garcin use the following technic: Five days before operation a daily injection of 10 cc. of a 5 per cent solution of calcium chloride, and two days before operation a daily intramuscular injection of 10 cc. of the proprietary drug mentioned also is given. Thirty prostatic cases have been treated with success in this manner; it was not necessary to use packing in any case.

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56. Legueu, F., and Garcin, A.: Le traitement preventif des hemorragies dans la prostatectomie transversicale, Semaine d. hôp. de Paris **2**:41-45, 1925.

Prostatitis.—Belostozky [57] reviews the literature on the development of our knowledge of acute prostatitis and quotes the work of Segond, Desault and Petit, Lallemand, Dugas, Begin, Velpeau and others on the pathology of the condition.

While the possibility of aseptic prostatic abscess is not to be denied, in by far the greater number of cases pathogenic organisms are the inciting cause. Of these the gonococcus takes first place. However, the other pyogenic organisms, such as the staphylococcus, streptococcus and colon bacillus, may by themselves or, more frequently, in association with the gonococcus, produce the condition. Staphylococcus and streptococcus prostatitis not associated with gonococcal infection are not infrequent; Belostozky cites a number of such instances. Segond found no disease in the posterior urethra in twelve of 115 cases, while Belostozky found the posterior urethra uninvolved in only five of seventy cases. Metastatic prostatic abscess occurs rarely. Of etiologic moment may be mentioned severe physical work, chilling, excessive sexual indulgences, irritation from riding and the like, but these are to be considered predisposing rather than direct causes. Not infrequently prostatic abscess may develop from forced urethral irrigation or instrumentation. Three symptoms are constantly observed, prostatic enlargement by rectal palpation, pain in the anal region and difficulty in urination. In twenty-one of the seventy cases there was complete urinary obstruction so that the catheter had to be used. Eighteen of the seventy cases ran an afebrile course. There was no relation between the severity of the course of the disease and the size of the abscess. In forty of the cases the disease subsided by rupture of the abscess into the urethra or the rectum. Some authors hold that this is practically always the mode of spontaneous cure. The abscess ruptured into the urethra in twenty cases, into the rectum in ten, and into both in three. The prognosis, so far as life is concerned, is good. None of the author's seventy patients died. Fistula formation is frequent. Two recto-urethral fistulas in the series healed spontaneously in a short time. The disease lasted an average of thirty days.

Conservative treatment consists in hot applications, rest, milk injection and vaccine. Gentle prostatic massage is undertaken after the abscess has begun to subside. Statistics show that the mortality when operation is performed runs higher than when conservative treatment is carried out. Belostozky operated on eight patients by drainage through a prerectal incision with good results. He feels that operation should be reserved for cases of such persistence or severity as will not respond

57. Belostozky, M.: 70 Fälle akuter eitriger Prostatitis, Ztschr. f. urol. Chir. **17**:53-60, 1925.

to conservative methods. Emphasis is placed on the good results to be obtained from injections of milk (nonspecific protein therapy).

[ED. NOTE.—The emphasis of persistent application of conservative measures in acute prostatic abscess rather than hurried operation corresponds to the usual urologic teaching in America. In certain cases nonspecific protein therapy gives brilliant results, but this is not consistent. However, if complete urinary retention is not relieved in a few days, if fever persists with recurrent chills, operation is indicated. Many surgeons still hold to perineal urethrotomy with breaking into the abscess through the prostatic urethra and subsequent perineal drainage of the prostatic urethra and bladder with an indwelling catheter.]

Legueu [58] states that while performing prostatectomy for adenoma one occasionally encounters a suppurative infection of the prostate; the infected section usually is soft and spongy and may contain pure staphylococci. The extent of the infection is, in a certain way, proportional to the volume of the tumor. It is situated in the prostatic tissue as well as in the adenoma, but its origin is always in the tumor itself and as soon as the latter is removed infection ceases. This condition may be secondary to a localized area of infection, especially in the skin. Catheterization may cause it, but in most cases the catheterization is necessitated by retention due to an unsuspected infection. The presence of the adenoma may cause the infection or it may develop during the course of a cystostomy. Legueu divides the infected prostatic adenomas from a clinical standpoint into three groups. The most common type is a simple prostatic suppuration: when this is the case the abscess must be opened through the perineum or an immediate prostatectomy may be performed, but this is undesirable. Legueu drains the abscess through the perineum, vaccinating the patient against his infection and then performing secondary prostatectomy. A second type of case is characterized by fever without suppuration. This type includes the patients with acute retention accompanied by a fever which is usually attributed to catheter infection but is really due to an infected adenoma.

In the same group are patients who have had cystostomy performed and develop fever several weeks or months after operation. Cystostomy is not always the cause of the fever in these cases; there may have been an infected adenoma present before operation, and in such case it is better to wait and operate when all symptoms of infection have subsided, although sometimes surgical intervention is necessary on account of a persistent fever, in which case the removal of infected adenomas may bring about a complete cure. Legueu has reported cases in which this infection had invaded the pelvis and caused pericystitis. In the third

58. Legueu: Les infections de l'adenome prostatique, Le Monde médical, 1925, pp. 297-303.

type a partial or total induration of the prostate may be found. On account of the hardness of the prostate the condition is thought to be malignant, but there is less induration in the region of the seminal vesicles than occurs with cancer, and eosinophilia may be present. In these cases a two-stage prostatectomy should be done which permits the prostate to regress after cystostomy and at the same time affords an opportunity to improve the patient's general health before the gland is removed.

Blanc [59] states that patients with enlarged prostates and infected urine should be divided into two groups, those who have been catheterized and those who have not. If the patient has not been catheterized and the enlargement of the prostate is of recent origin, the urine should be clear; if it is not, some other part of the urinary tract is affected. If the enlargement is old and there is some residual urine, although the colon bacillus frequently provokes chronic cystitis, the pyuria should be considered as evidence of some other lesion. If the patient has been catheterized the chances are, especially if he has been frequently catheterized, that he has an infected prostate, but if the catheter has only been occasionally passed and the urine is very purulent, vesical or renal lesions must be thought of. Blanc reports nine cases of prostatic infection with pyuria, in which there were also renal and vesical calculi, large ureters, diverticula and renal and prostatic tuberculosis.

TESTIS

Tumors.—Bell [60] studied fifty specimens of tumors of the testis. These represent most of the various types of testicular tumors commonly described but thus far there has been little unanimity of opinion as to their proper classification and origin. In Bell's series most of the tumors fell into two main groups, the teratoid and the germinal cell. The latter group has been variously designated germinal cell carcinoma, seminoma, spermatocytoma, embryonal carcinoma and round cell sarcoma. The teratoid group predominated to a marked degree. In this group perhaps the most popular of the various designations has been fibrocystic disease, a term justified by the naked eye and lower magnification appearance of cysts supported by a matrix of fibrous tissue. Various other terms, such as chondroma, chondrosarcoma, chondroadenoma, osteoma, adenoma, squamous cell and columnar cell carcinoma, are referable to the most obvious histologic features, occasionally displayed, which have dominated the mind of the pathologist. These older terms serve as an indication of the remarkable structural varia-

59. Blanc, H.: La pyurie chez les prostatiques, J. d'urol. med. et chir. **19**: 506-512, 1925.

60. Bell, F. G.: Tumours of the Testicle: The Teratoid Group, Brit. J. Surg. **13**:738 (July) 1925.

tions presented by these tumors, which are now regarded as variations from a common teratoid basis. These tumors vary greatly in size, shape and consistency. The internal structure is best demonstrated by sagittal section, which brings out the relation of the tumor to the body of the testis and to the epididymis, and may, in early specimens, clearly demonstrate its frequent origin from the mediastinum testis. In the early stages the body of the testis is usually visible to the naked eye at some part of the periphery of the tumor, commonly at the summit, and may be fairly normal in shape and size, while in large tumors it undergoes progressive compression till it is reduced to a narrow straplike peripheral layer only detectable under the microscope. The presence of a peripheral band of testicular tissue separated from the substance of the tumor by a condensed fibrous layer or capsule is highly characteristic of teratoma, but not pathognomonic. Many specimens are cystic, and some are cartilaginous. Teratoma of the testis displays histologic characters of a highly variable complexity, and the individual representation of the blastodermic layers varies greatly in different specimens. After examining a considerable number of these tumors it is possible to reduce them to a group type. A brief description is as follows:

Mesoblastic Derivatives: The presence of cartilage in the form of round or oval nodules or crescentic plates is characteristic. A fibrocellular myxomatous matrix, sometimes sarcomatous, is almost equally characteristic and always suggests that any tumor under consideration is teratoid in character.

Hypoblastic Derivatives: These take the form of tubules or spaces lined by cubical or columnar cells, often suggesting the glandular structures in adults, especially intestinal mucosa.

Epiblastic Derivatives: These take the form of spaces lined by stratified squamous epithelium, and cell nest formation is often a striking feature.

Metastasis may take place by the lymphatics, the blood, or both, depending on the predominance or admixture of carcinomatous or sarcomatous elements. It is also possible that transplantation of fragments of tumor may take place from comparatively innocent tumors, such as the chondromatous teratoma, by direct invasion of venous channels. Paget's enchondroma is often regarded as an example of this, and the secondary tumors in the lung, as produced by transplantation after erosion of the spermatic vein.

Hinman, Gibson and Kutzmann [61] report in detail twenty-two cases of malignant tumor of the testis. Ten were diagnosed teratomas or mixed tumors and twelve as seminomas or single cell tumors. Sarcoma

61. Hinman, Frank; Gibson, T. E., and Kutzmann, A. A.: Malignant Tumors of the Testicle; a Pathological Study, Ann. Surg. **82**:552-575 (Oct.) 1925.

of the testis is rare; there were none in this series. All the tumors were malignant. Hinman asserts that practically all tumors of the testis are teratomatous in origin, and that practically all exhibit some type of carcinomatous degeneration of which the so-called seminoma is but a modification. Clinically it is now fairly well established that the seminoma is relatively susceptible to radiotherapy, whereas other types of teratoma are less favorably influenced.

Triorchidism.—Holder [62] stated that proved cases of triorchidism are rare. He reports the case of one in a man, aged 45, whose chief complaint was pain in the left inguinal region. Physical examination led to a provisional diagnosis of cellulitis of the affected tissues, or adenitis of the inguinal lymph nodes. After twenty-four hours' observation the area was incised and pus evacuated. On the eighteenth day, the patient having grown worse, the "infected glands" were removed. Examination of the tissue removed showed differentiated testicular tissue, vas deferens and epididymus. As there were two normally placed testes in the scrotum, Holder seems to be justified in assuming this to be a case of triorchidism. It is probably the second case to be reported of a third functioning testis.

URETHRA

Tuberculosis.—Minet in 1910 could find only seven cases of tuberculosis of the urethra reported in the literature. Boeckel and Oberling [63] reported a case of a man, aged 35, who was sent to them to be treated for urethritis. He had had pulmonary tuberculosis. The lesion of the urethra had been noted four months before, starting with a sudden urethral discharge followed two weeks later by swelling, without apparent sign of inflammation, in the right perineal region. Gonococci were found in the urethral discharge. Potassium permanganate solution was injected but without success. The swelling increased, forming a mass measuring about 7 by 7 cm. below the prostate; it was adherent to the deeper tissues. Cystoscopic examination of the prostate and bladder was negative. The mass was excised; it contained bacilli of tuberculosis. Some of the urethral discharge injected into a guinea-pig produced tuberculous lesions. A few weeks later, definite tuberculous granulations appeared in the urethra. The patient died subsequently of pulmonary tuberculosis. Postmortem examination revealed the presence of nodular fibrous tubercles of the urethra, there were also a periurethral abscess and a prostatic abscess that was completely isolated

62. Holder, H. G.: A Probable Case of Triorchidism, J. Urol. **13**:555-564 (May) 1925.

63. Boeckel, André; and Oberling, C.: Un cas de tuberculose de l'urethre, J. d'urol. med. et chir. **19**:127-131, 1925.

from the urethra, a few tuberculous ulcerations in the bladder and, finally, a beginning caseous tuberculosis of the left kidney. These lesions evidently had their origin in the pulmonary tuberculosis. The renal and vesical lesions were recent, independent of the urethral and periurethral lesions. The prostatic abscess probably also formed afterward. These facts were established both clinically and pathologically. The periurethral mass removed at operation was an old lesion, which certainly preceded the symptoms of urethritis. There was a urethral stricture present, probably caused at first by the periurethral mass; it was relieved only partially by removal of the tumor. At necropsy it was found that there was also an area of tuberculous narrowing of the urethra, a fibrous lesion of the urethral wall itself which was covered with tuberculous nodules.

Valvular Obstruction.—Hinman and Kutzmann [64] report six cases of congenital valvular obstruction of the posterior urethra and review fifty cases from the literature. They find that such obstruction occurs mainly in early boyhood, most of the cases (62 per cent) occurring prior to the age of 10 years, and is serious because irremediable pressure changes may have already occurred or recognition of the obstruction be delayed during childhood beyond the period when intervention could cure the disease. It is probably more common than the few reported cases indicate, and this tardy recognition of a condition so often fatal warrants recording their six cases, with a full discussion of cases reported by others. The importance of a knowledge of the obstruction by the practitioner and pediatrician, on whom the first responsibility of diagnosis rests, is apparent in view of the ease with which it can be recognized cystoscopically and the great benefit of early treatment.

The condition has been recognized for more than a century but it is only recently that correct diagnoses have been made during life. The etiology is still a matter of conjecture. Occurrence of the obstruction in the stillborn and in young infants points strongly to an embryologic basis. The early symptoms are chiefly those of urinary obstruction and infection; later, renal insufficiency occurs. A correct diagnosis is possible only after careful history taking and a thorough urologic investigation which may include cysto-urethroscopy, urography and a study of renal function. A clinical diagnosis was made in six cases reported by the authors.

The treatment is not difficult and consists in the destruction of the valves by fulguration through the cystoscope or by radical surgical intervention suprapubically or perineally or by combining the two methods of approach.

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64. Hinman, Frank; and Kutzmann, A. A.: Congenital Valvular Obstruction of the Posterior Urethra, J. Urol. **14**:71-112 (Aug.) 1925.

The early incidence of the condition, its insidious nature, gradually causing, as it does, serious renal damage that may soon become irremediable and result fatally; its recognition by proper methods of examination and the fact that if recognized early it can be easily cured emphasize the extreme clinical importance of congenital valvular obstructions of the posterior urethra.

Huddy [65] classifies urethral pouches as congenital or acquired. The acquired type may be caused by dilatation or perforation of the urethra from stricture, calculus, injury or infection. The pouches vary greatly in size but those giving rise to symptoms are usually about 3.5 cm. in diameter. Sisk is quoted as saying that only eighty cases have been reported in the literature; this, however, probably exaggerates their rarity. Many hypotheses have been advanced to explain the origin of the congenital pouch. As the cavity is found on the ventral aspect of the urethra, two explanations are imperfect fusion of the two genital folds and the fact that one of the cystic epithelial ducts may retain its urethral communication and become dilated. Some of the pouches, however, may arise from the müllerian ducts, but these are probably very rare. Clinically, urethral pouches are of two types. In the first type the patient presents himself with rather vague and indefinite symptoms, and a diagnosis can be made only by means of the urethroscope. In the second type swelling at some point along the urethra is found.

URINARY INFECTION

Shaw and Hill [66] report an epidemic of thirty-six cases of wound infection, observed in the urologic wards of the Johns Hopkins Hospital. The infection occurred only in wounds that were the site of urinary drainage. In thirty-four cases it followed perineal prostatectomy and in two cases occurred in suprapubic wounds. The appearance of the lesions clinically and the course of the infection were characteristic. The essential features were: pain in the incision, a rolled-up appearance of the skin margin, and the formation of a dirty gray membrane that would subsequently become black and slough. Invariably the wounds gave off a strong ammoniacal odor. In untreated cases the membrane often reformed and the process repeated itself. There was little or no constitutional reaction. The temperature usually remained normal and the leukocyte count rarely exceeded 10,000. The wounds were painful and frequently opiates were necessary. The etiologic organism was a gram-positive bacillus with some cultural characteristics similar to the

65. Huddy, G. P. B.: Urethral Pouches, Brit. J. Surg. **13**:50-57 (July) 1925.

66. Shaw, E. C., and Hill, J. H.: Report of a New Pathogenic Organism (Corynebacterium Thompsoni) with Description of an Epidemic of Infection of Urinary Fistula, J. Urol. **13**:689-713 (June) 1925.

diphtheria bacillus, but differing from it in certain morphologic features and in pathogenicity. The authors have proposed the name of *Corynebacterium thompsoni* for this species. The organism was seen in direct smears from the lesions and obtained by culture in every case that showed the infection clinically. On making cultures from the hands of all those coming in contact with the patient, it was found that the infection was propagated by the orderlies. The usual antiseptics were useless in combating the infection. Most of the cases cleared up promptly under local application of 5 per cent acetic acid, and by spraying the wounds of the patients with 1 per cent acetic acid solution infection was prevented. The etiologic organism was studied in reference to its pathogenicity for rabbits and guinea-pigs. It was found impossible to infect the normal urethral mucous membrane of rabbits by injections of cultures or to infect surface wounds that were not draining urine. After producing a suprapubic urinary fistula, however, inoculation was invariably successful, being followed by the appearance of the same type of lesion that occurred in man. The organism was recovered by culture in every case. These lesions did not occur in uninoculated urinary fistulas or in those inoculated with proteus.

[ED. NOTE.—Two cases have occurred in the urologic wards of St. Michael's Hospital, Toronto, within the last year, which appeared and behaved clinically like those described by Shaw and Hill. The first case was that in which a two stage suprapubic prostatectomy had been performed and this type of infection occurred after the primary drainage. After a prolonged course it cleared up only to recur after the prostatectomy was performed. The patient recovered after a stormy convalescence but has a hernia. The second infection occurred after primary suprapubic prostatectomy; unfortunately the causative organism was not isolated, but otherwise the case resembled in every respect those described by Shaw and Hill. Recovery was spontaneous although protracted. The two patients were not in the hospital at the same time.]

Henline,[67] after a review of fifty cases of urinary infection treated with hexylresorcinol, asserted that careful urologic examination should be made of all such infections before treatment is instituted. Such examinations should include cultures, tests of renal function and roentgenograms. Hexylresorcinol is a superior urinary antiseptic, as it may be administered by mouth and is nonirritating to the urinary tract. It is bactericidal for all organisms infecting the urinary tract. An average of sixty-three days for *Bacillus coli,* eighteen days for *Staphylococcus aureus,* ninety-four days for *Bacillus proteus,* ninety-one days for *Bacillus lactis-aërogenes,* and 133 days for mixed infections, was neces-

67. Henline, R. B.: Hexylresorcinol in the Treatment of Fifty Cases of Infections of the Urinary Tract, J. Urol. **14**:119-133 (Aug.) 1925.

sary to sterilize the urine. Only one case recurred, and in this one treatment was discontinued too soon. Ninety-two per cent of the patients were cured. Of the three that were not cured, one did not return for treatment, one still had a growth of *Bacillus fluorescens,* and one had a tumor of the bladder as a complication. These three are cured clinically.

Henline suggests that the drug may be useful in preventing recurrence of stones, and in the healing of sinuses if there is streptococcal infection.

Scott and Hill,[68] after extensive investigation of the subject of preoperative skin disinfectant in which comparative studies were made as to the value of several substances in general use and considered relatively satisfactory, conclude that an alcohol-acetone-aqueous solution of mercurochrome is most effective. This solution is made by dissolving 2 Gm. of mercurochrome in 35 cc. of distilled water and then adding 55 cc. of 95 per cent alcohol solution and 10 cc. of acetone. This solution is found to be more efficient than tincture of iodine, potassium mercuric iodide or picric acid. It is particularly valuable in local anesthesia because its application is entirely painless and does not cause local dermatitis. It penetrates as deeply as does picric acid and more deeply than iodine or potassium mercuric iodide. The solution is quite stable and retains its bactericidal power for at least forty-six days. Its color serves as a useful guide as to the thoroughness of the preparation. Its toxicity is low.

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68. Scott, W. W., and Hill, J. H.: Presentation of a Preoperative Skin Disinfectant, an Alcohol-Acetone-Aqueous Solution of Mercurochrome, J. Urol. **14:** 135-152 (Aug.) 1925.